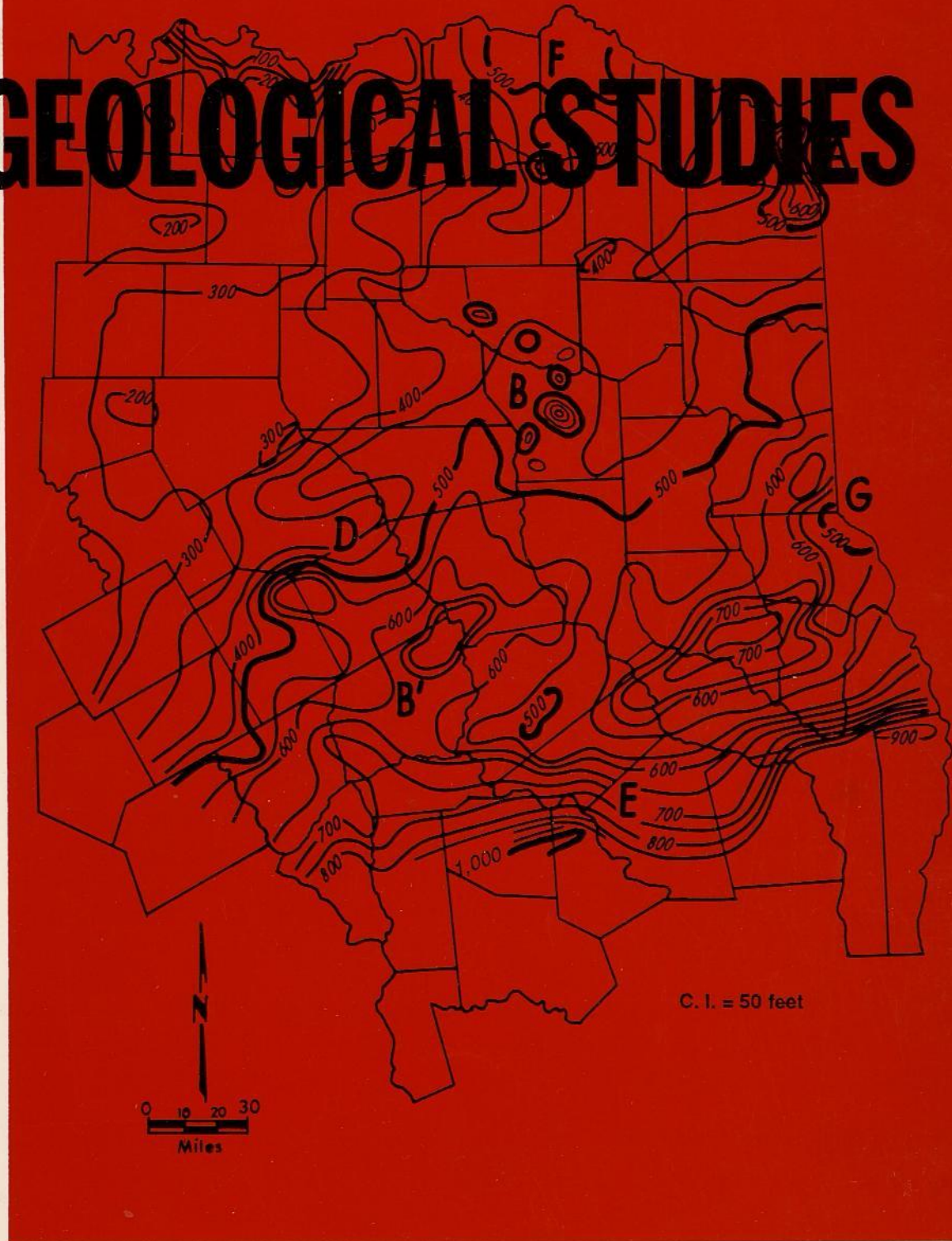
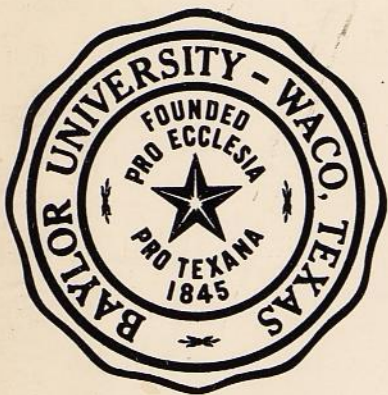


BAYLOR GEOLOGICAL STUDIES

SPRING 1989
Bulletin No. 47



*Stratigraphy of the Fredericksburg
Group, East Texas Basin*

L. MARLOW ANDERSON

*"Creative thinking is more important
than elaborate equipment--"*

FRANK CARNEY, PH.D.
PROFESSOR OF GEOLOGY
BAYLOR UNIVERSITY
1929-1934

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The training of a geologist in a university covers but a few years; his education continues throughout his active life. The purposes of training geologists at Baylor University are to provide a sound basis of understanding and to foster a truly geological point of view, both of which are essential for continued professional growth. The staff considers geology to be unique among sciences since it is primarily a field science. All geologic research including that done in laboratories must be firmly supported by field observations. The student is encouraged to develop an inquiring objective attitude and to examine critically all geological concepts and principles. The development of a mature and professional attitude toward geology and geological research is a principal concern of the department.

Cover: Isopach of the Fredericksburg Group.

BAYLOR GEOLOGICAL STUDIES

BULLETIN NO. 47

Stratigraphy of the Fredericksburg Group,
East Texas Basin

L. Marlow Anderson

BAYLOR UNIVERSITY
Department of Geology
Waco, Texas
Spring 1989

Baylor Geological Studies

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ISSN 0005-7266

Additional copies of this bulletin can be obtained from the Department of Geology, Baylor University, Waco, Texas 76798.

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Stratigraphy of the Fredericksburg Group, East Texas Basin

L. Marlow Anderson

ABSTRACT

The lower Cretaceous Fredericksburg Group is a classic example of a time-transgressive unit. This major group consists, on outcrop in central Texas, of the Paluxy Sand, the Walnut Clay, the Comanche Peak Limestone, and the Edwards Limestone. In north Texas and in the East Texas basin, it is commonly accepted to be represented by the Paluxy Sand, Walnut Clay, and the Goodland Formation (Comanche Peak and Edwards equivalent). However, electric log analysis and mapping of Fredericksburg rocks on a regional scale in the basin show the Goodland to be differentiable.

Initial Fredericksburg sedimentation began with south-flowing Paluxy fluvial systems shed from the Oklahoman Ouachita-Arbuckle trend. Minor streams fed the basin from the west. This progradation developed

a complex facies network of intertonguing strandline, fluvial, lagoonal-embayment, and deltaic deposits. The distal Paluxy interfingered with the time-equivalent basinal Walnut Clay. Gradual cessation of Paluxy clastic influx, accompanied by slow basin subsidence, allowed the slow northwestward encroachment of Walnut facies. Continued inundation across the northern basin brought marine conditions, and by the time of Edwards deposition, marine waters covered the greater part of the basin. Basinal depocenters existed during emplacement of Paluxy, Walnut, and Comanche Peak Formations. However, by the time of Edwards deposition, a stable shallow back-shelf lagoon had evolved. Fredericksburg deposition ended with Kiamichi clastic invasion and subsidence of the basin.

INTRODUCTION*

PURPOSE

The most widely exposed and perhaps the most thoroughly studied stratigraphic unit in the Comanchean outcrop belt in Texas is the Fredericksburg Group, which has been a focus of geological attention for more than a century. This rock group plunges into the subsurface beneath the Tertiary rocks of the East Texas basin, where, because it has not been widely productive, it is almost ignored. However, the history of this rock group is an important element in the evolution of the East Texas basin and the Comanchean shelf. Therefore, it is the purpose of this investigation to describe the stratigraphy of the Fredericksburg rocks of the East Texas basin (Fig. 1), and, on the basis of that description, to interpret the history and relationship of the rocks to the evolution of the basin.

LOCATION

The area of interest lies in northeastern Texas in the

East Texas basin, which is bounded by the Arbuckle/Ouachita system, the Sabine Uplift, the Angelina-Caldwell Flexure, and the Central Texas Platform (Fig. 2). Figure 3 shows the 62 counties of the study area. These will be referred to later in the text.

The Fredericksburg outcrop belt comprises the physiographic regions of the Lampasas Cut Plain which merges northward into the Fort Worth Prairie and Western Cross Timbers to the Red River (Fig. 4). Southward, it merges into the Edwards Plateau. The Fredericksburg strata dip gently to the south-southeast and east into the subsurface along the northern and western margins of the basin.

METHODS

The principal methods used in this investigation include: (1) correlation and interpretation of electric well logs; (2) construction of regional stratigraphic cross

*A thesis submitted in partial fulfillment of the requirements for the M.S. degree in Geology, Baylor University, 1987.

EAST TEXAS BASIN			
	NORTH	CENTRAL	SOUTH
WASHITA GROUP	DUCK CREEK FORMATION	DUCK CREEK FORMATION	DUCK CREEK FORMATION
	KIAMICHI FORMATION	KIAMICHI FORMATION	
FREDERICKSBURG GROUP	GOODLAND FORMATION	EDWARDS FORMATION COMANCHE PEAK FORMATION	GOODLAND FORMATION
	WALNUT FORMATION	WALNUT FORMATION	
	ANTLERS FORMATION (PALUXY EQUIVALENT)	PALUXY FORMATION	WALNUT FORMATION
TRINITY GROUP	(PALUXY EQUIVALENT)	GLEN ROSE FORMATION	GLEN ROSE FORMATION

Fig. 1. Stratigraphic column of Fredericksburg strata within the East Texas basin. The basin can be divided into three distinct stratigraphic areas. In the northern basin, the Fredericksburg is represented by the Upper Antlers Formation (Paluxy equivalent), the Walnut Formation, and the Goodland Formation. In the central basin, the Fredericksburg comprises the Paluxy Formation, the Walnut Formation, the Comanche Peak Formation, and the Edwards Formation. In the southern basin, the Fredericksburg is made up of the Walnut Formation and the Goodland Formation.

sections; (3) construction of isopach and lithofacies maps on significant stratigraphic units; (4) analysis of conventional cores¹; (5) seismic interpretation (Fig. 5)²; (6) field reconnaissance in the outcrop belt of Fredericksburg rocks; and (7) an extensive review of previous works concerning the Fredericksburg, the Comanche Series of the East Texas basin, and depositional models of shallow epeiric environments.

PREVIOUS WORKS

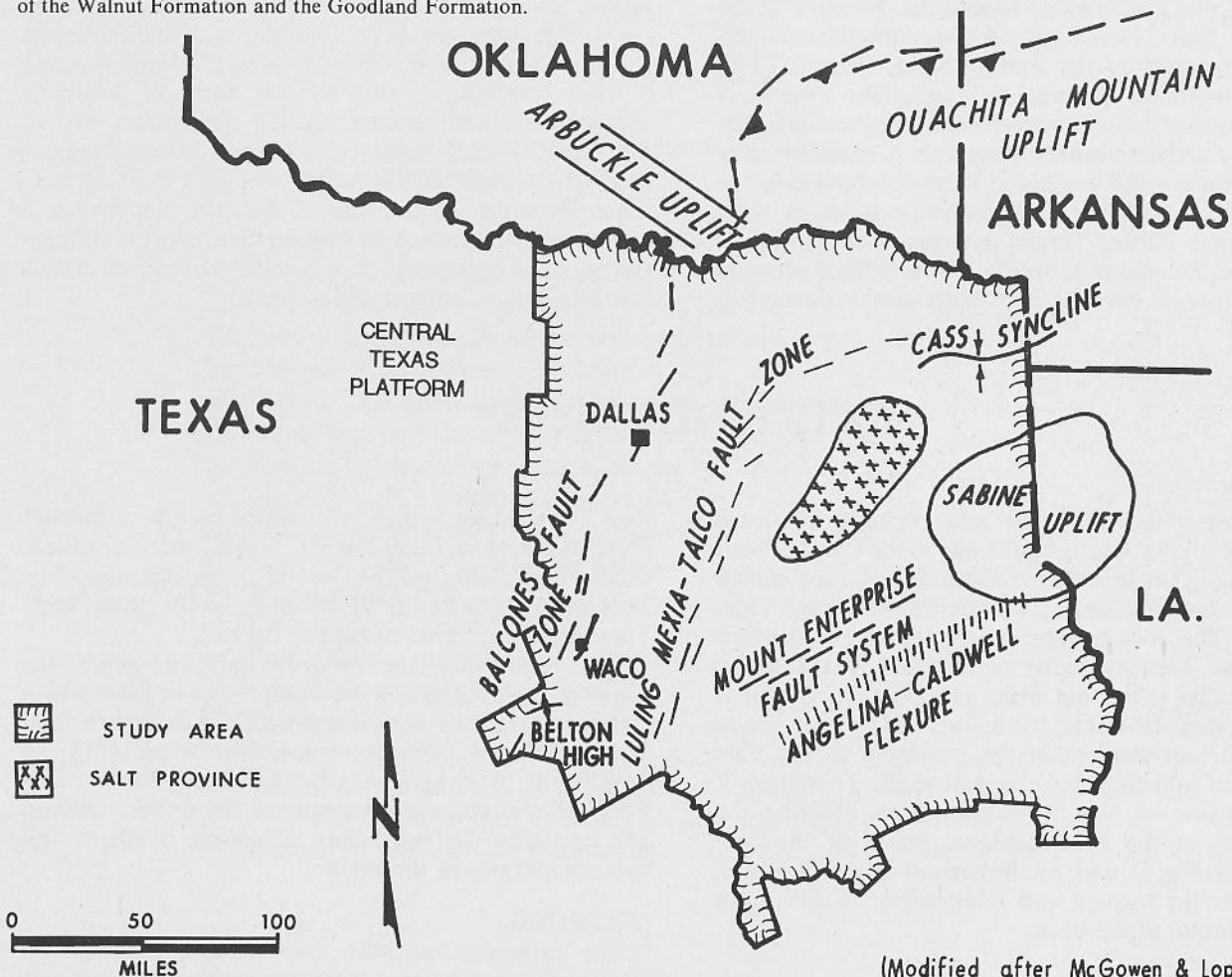
As in any study of an area of this magnitude, a major element is based upon existing literature. Therefore, an extensive review of the literature on Fredericksburg rocks of the East Texas basin, the Fredericksburg rocks of the marginal areas to the basin, basin history, and depositional environments was undertaken. A compilation of these previous works is presented as an Appendix.

ACKNOWLEDGMENTS

Sincere gratitude is expressed to O.T. Hayward, who

¹Core data in the form of descriptions and photographs are available in the original text at Baylor University.

²Seismic control is shown on Figure 5, but individual seismic cross sections are only available in the original text.



(Modified after McGowen & Lopez, 1983, p3)

Fig. 2. The East Texas basin, showing the boundaries of the study area. The Arbuckle-Ouachita system serves as the northern boundary, the Sabine Uplift as the eastern boundary, the Angelina-Caldwell Flexure as the southern boundary, and the Central Texas Platform as the western boundary.

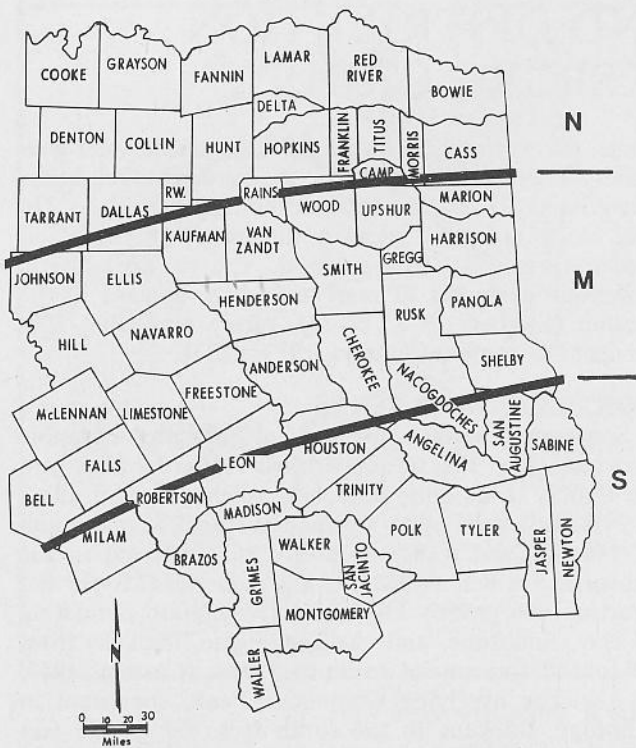


Fig. 3. Index map of the study area, showing the county lines and names for reference purposes. The northern, middle, and southern basins are indicated. These are characterized by differing Fredericksburg stratigraphy, a product of sediment supply, basinal tectonics, and possible eustatic changes in sea level.

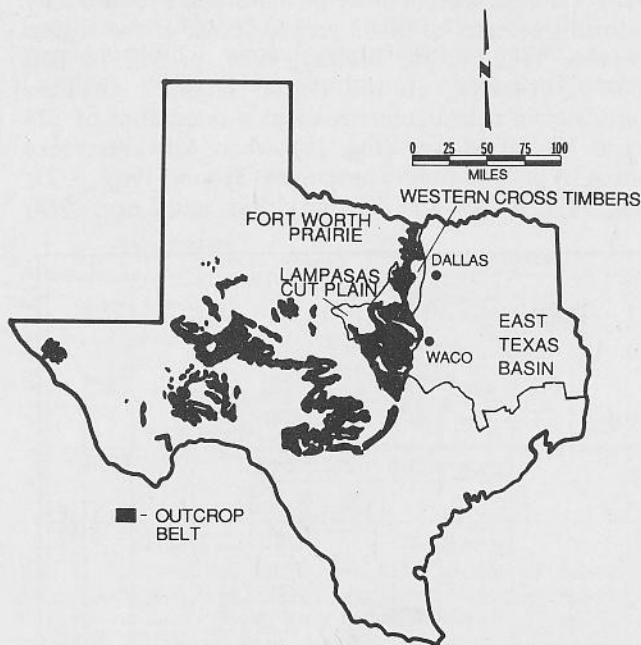


Fig. 4. Physiographic index map of Fredericksburg outcrop regions throughout Texas. The outcrop belt bordering the study area lies within the Lampasas Cut Plain, Fort Worth Prairie, and Western Cross Timbers. Fredericksburg strata dip gently to the east-southeast into the subsurface into the East Texas basin and extend westward to disappear beneath Miocene-Pliocene deposits of the Llano Estacado. Present distribution suggests that at one time they covered all of Texas.

supervised this study. His continuous guidance, encouragement, and sense of humor made the path easier. Deep appreciation also goes to Robert C. Grayson, Jr., who played more than the role of a second reader. His direction challenged my thoughts throughout this investigation. My thanks are also extended to the entire faculty of the department. These seasoned geologists have instilled in me a deeper appreciation and greater knowledge of geology.

I gratefully acknowledge those who provided material and financial support: Marshall Exploration Company (through the efforts of Jack Trice); Cecil E. Boykin, Shell Development Company; Diane Barnes, Geomap, Inc.; and the University of Texas Bureau of Economic Geology. Special thanks go to Lucille Brigham, Brian Lock, and Viola Shivers for editing this manuscript and Hoffman Hibbett for drafting the figures.

Thanks are also due to all my contemporaries within the graduate department. Sincere appreciation must be given to special friends, officemate David Lemons, roommates Susan Haycock and Carol Hoadley, and best friend, Roland Clubb.

I am forever indebted to my parents, Robert and Rose Anderson, and my family for their sustaining support, encouragement, and love throughout my life.

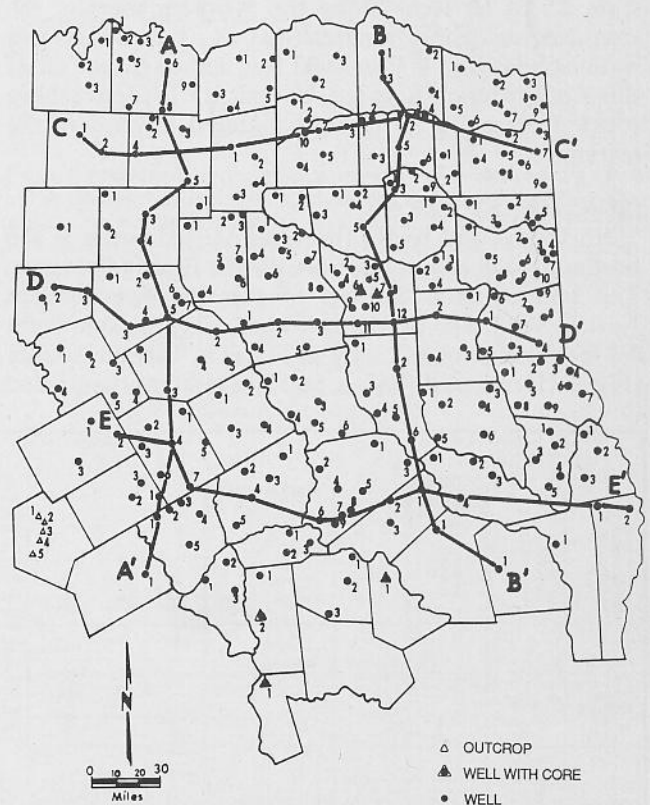


Fig. 5. Map of well and core localities, and lines of section that were principal elements in the investigation. Well coverage was selected to emphasize regional trends within the basin; numbering is on a per county basis. Particular effort was given to selecting those least affected by local structural elements. Interpretation of depositional environments was based principally on log signatures, since cores were limited in distribution and availability. However, those that were available were studied in some detail.

REGIONAL NATURE AND DISTRIBUTION OF THE FREDERICKSBURG GROUP

The Fredericksburg Group and its equivalents within the Lower Cretaceous Comanchean Series extend across the North American continent. Changes in lithology, stratigraphic nomenclature, and character of the section create a complex facies network in the East Texas basin and surrounding areas. It is the purpose of this section to describe the nature and distribution of the Fredericksburg Group in the East Texas basin and those neighboring areas that may have important bearing on deposition within the basin (Figs. 6 and 7).

EAST TEXAS BASIN

The Fredericksburg Group is a clastic-carbonate "package" which thickens progressively from 100 feet in the north to 900 feet to the south-southeast (Fig. 8). It is composed largely of carbonates with basal Paluxy sand pinching out to the south, while the Walnut Formation thins northward. Comanche Peak sediments thicken to the southeast, while the overlying Edwards Formation maintains a uniform thickness of 25 feet for the greater part of the basinal area. The Goodland Formation in the northern margin varies in thickness from 25 to 60 feet. Along the southern margin, the southwest-northeast trending Stuart City Reef increases in thickness from 100 to 1000 feet, although not all of this is of Fredericksburg age. Overall, the Fredericksburg rocks decrease in terrigenous material upward in the section.

NORTHEAST TEXAS

Northwest and updip from basinal sediments is the bordering outcrop in the Fort Worth Prairie Province. The basal section consists of the Paluxy-equivalent Antlers Sand. The overlying Walnut Clay thickens from 4-7 feet near Cooke County to 30 feet in Tarrant County (Fig. 9) (Hendricks, 1967, p. 56-57). This thinly laminated

shale, most often containing a *Texigryphea* oyster bed, thins northward to 0.5 feet in southern Oklahoma (Sandlin, 1973, p. 55-56). Thickening from 26 to 116 feet along the same trend is the overlying Goodland Formation. The fine-grained, sparse biomicritic limestone decreases in marl and shale upward in the section (Staples, 1977, p. 17), rarely exceeding 10% terrigenous content (Sandlin, 1973, p. 31).

NORTH CENTRAL TEXAS

Southward, in the Lampasas Cut Plain physiographic province (Fig. 10), the uppermost Antlers grades into the Paluxy sands, silts, clays, and caliche (Corwin, 1982, p. 29). The basal Paluxy Formation reaches a maximum of 140 feet and thins southward to pinch out in the subsurface in Bell and McLennan Counties (Moore and Martin, 1966, p. 985). The Walnut Formation, consisting of clay, limestone, and shell aggregate, thickens from 60 to 180 feet to the south-southeast (Corwin, 1982, p. 32). The overlying Comanche Peak, consistent in lithology, thickens to the south from 60 to 125 feet (Corwin, 1982, p. 33). The Goodland grades into both the Comanche Peak nodular limestone and marl and the Edwards rudist-bearing limestone (Corwin, 1982, p. 33-34). The pure limestone and rudist mounds are unique to the Edwards Formation of the platform, though a facies equivalent to the Edwards can be recognized over almost all the Goodland outcrop belt (Lemons, 1987, p. 98). The Edwards, in outcrop, maintains a remarkably uniform thickness of 30-35 feet for most of the region (Corwin, 1982, p. 34; Walker, 1984, p. 58). In Bell County, however, on the Belton High, it thickens drastically in a lenticular trend to a maximum of 125 feet at Moffat Mound (Fig. 10), where Edwards rocks consist of pelletal-oolitic limestone (Moore, 1964, p. 21; Kerr, 1977, p. 217; and Amsbury, Bay, and Lozo, 1984,

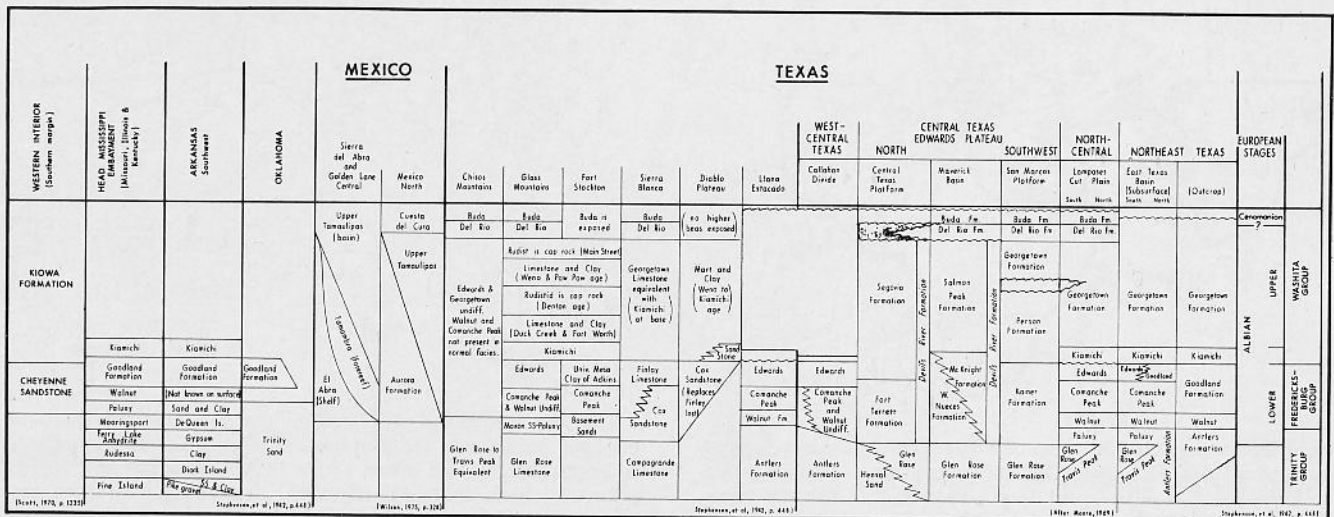
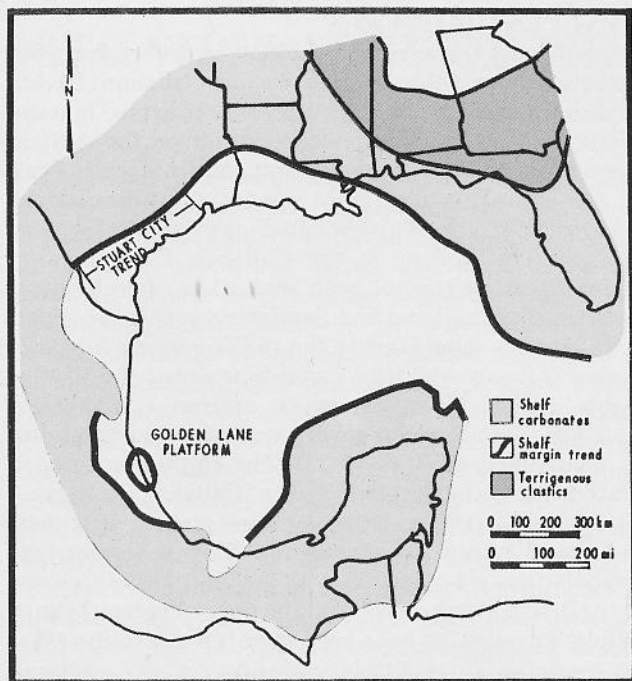


Fig. 6. Correlation chart for the Lower Cretaceous units, including Texas, Mexico, and the southern margin of the Western Interior of the United States.



[After Meyerhoff, 1967, pg. 56]

Fig. 7. Distribution of Lower Cretaceous shelf facies around the ancestral Gulf of Mexico. The shelf margin reef trend extended southward into Mexico and eastward as far as Cuba. Fredericksburg rocks also have correlatives in areas shown in Figure 13.

p. 18). The upper contact with the Washita Group is unconformable within the Lampasas Cut Plain (Corwin, 1982, p. 38). Where the Kiamichi is present, from Tarrant County to McLennan County, the contact is a nondepositional unconformity (Nelson, 1959, p. 30; Lambert, 1979, p. 12). Southward, where the Kiamichi

is absent, the Duck Creek disconformably overlies the Edwards (Keyes, 1976, p. 17). This surface is also a nondepositional unconformity (Corwin, 1982, p. 39).

CENTRAL TEXAS

The Edwards Group exists to the west-southwest in the Edwards Plateau region (Rose, 1972, p. 3). In the subsurface San Marcos Platform subprovince, the limestone and dolomite sequence is divided into two formations. The lower Kainer Formation (400') is correlative with Fredericksburg rock, and the upper Person Formation (200') is equivalent to the Washita unit (Fig. 11) (Rose, 1972, p. 12, 18, 19). The conformable Group boundary is placed at a consistent argillaceous, wispy biomicrite termed the Regional Dense Member (a Kiamichi equivalent) (Rose, 1972, p. 19, 20). Thickening to the south, the Kainer and Person

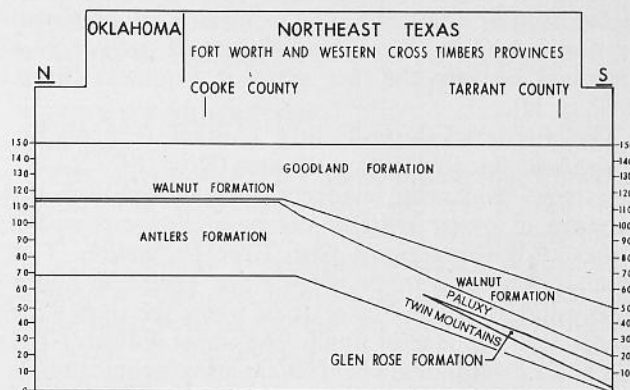


Fig. 9. A generalized north-south cross section of Fredericksburg rocks of the outcrop belt in southern Oklahoma and northeast Texas. The Antlers Formation is shown to thin southward to Tarrant County. Further south, it grades laterally into the Paluxy and Twin Mountains (Travis Peak) sands. Similar subsurface trends exist in the northern portion of the East Texas basin.

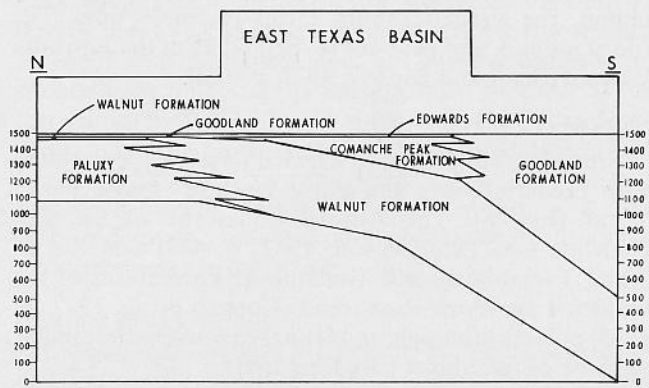


Fig. 8. A generalized north-south cross section of subsurface Fredericksburg rocks in the East Texas basin. Paluxy Sand is shown to pinch out to the south, while the Walnut thins dramatically to the north. Comanche Peak also thins to the north, however the Edwards maintains a uniform thickness throughout the central basin. Comanche Peak and Edwards thin slightly to the north and thicken to the south, merging to form the Goodland. The north-south trending outcrop belt marginal to the basin shares most of these trends. Where the Edwards and Comanche Peak merge together in the southern outcrop region, the massive limestone has been termed the Edwards Group (Rose, 1972, p. 49).

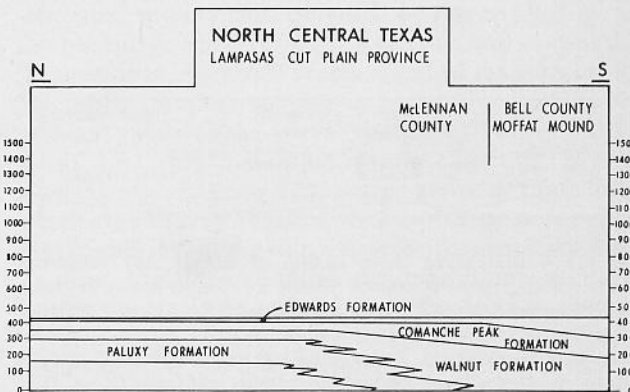


Fig. 10. A generalized north-south cross section of Fredericksburg rocks of the outcrop belt in north central Texas, Lampasas Cut Plain Province. Paluxy Sand thins southward, pinching out in McLennan and Bell Counties (in subsurface). Walnut and Comanche Peak Formations thin to the north, while Edwards maintains approximately the same thickness throughout the Cut Plain. The Edwards thickens dramatically to the south in Bell County. South of this point, the "platform" subsided during Fredericksburg deposition. Northward, it was stable throughout this interval.

formations grade into the rudist bank facies of the Devils River Formation that encircles the Maverick basin. Along this trend, maximum thickness is approximately 800 feet (Fig. 11; Rose, 1972, p. 64). The Edwards thins slightly to 600 feet in the Maverick basin (Rose, 1972, p. 64). Evaporites are commonly associated with the limestone and dolomite in the basin. Here the Group is separated, with the lower McKnight and West Nueces Formations correlative to Fredericksburg rocks, and the upper McKnight correlative to lower Washita rocks (Fig. 11; Rose, 1972, p. 65, 74). Northwestward, Fredericksburg rocks thin out of the Maverick basin and Devils River trend onto the Central Texas Platform subprovince. The lower Fort Terrett (Fredericksburg equivalent) thins from 300 to 160 feet (Rose, 1972, p. 32), and the upper Segovia (uppermost Fredericksburg-Washita equivalent) thins from 360 to 230 feet (Rose, 1972, p. 35). Lithologically, the two formations consist of limestones, dolomites, and evaporites. A persistent gypsum zone, the Kirschburg Evaporite, serves as a boundary between the two, where it is present (Rose, 1972, p. 34).

The Fredericksburg-Trinity contact is probably disconformable throughout the area (Rose, 1972, p. 30). The most convincing evidence for this belief is the presence of oyster marl of the basal Edwards within cracks of the uppermost Glen Rose Formation. This basal contact is with the Glen Rose, except in minor areas adjacent to the Llano Uplift where the Glen Rose grades into the Hensel Sand. The upper Edwards-Del Rio and Edwards-Buda contact are also disconformable (Rose, 1972, p. 45, 46).

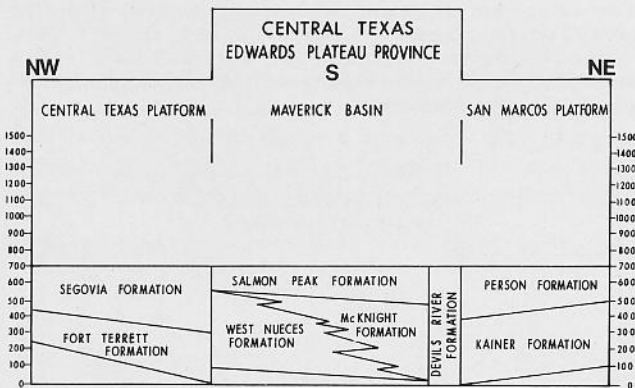


Fig. 11. A generalized cross section of surface and subsurface Fredericksburg rocks in central Texas, Edwards Plateau Province. Within the San Marcos Platform subprovince, the Kainer Formation is the Fredericksburg equivalent and the overlying Person Formation is the Washita equivalent. Both gradually thicken to the south merging to form the Devils River Formation, a rudist reef facies (Rose, 1972, p. 1). Further southward, in the Maverick Basin, the Salmon Peak and uppermost McKnight Formations are equivalent in age to the Washita, and the lower McKnight and West Nueces Formations equate to the Fredericksburg (Rose, 1972, p. 65). The formations thin northward out of the basin area. Terminology once again changes northwest of the basin into the Segovia and Fort Terrett Formations, which also thin northward (Rose, 1972, p. 32, 65). Fredericksburg rocks of the Plateau region reflect shallow water shelf and euxinic evaporitic basin conditions with little or no clastic influx, in contrast to the East Texas basin, where land-derived clastics constitute a significant element in Fredericksburg rocks.

WEST CENTRAL TEXAS

Northward from the Edwards Plateau region, the Fredericksburg thins slightly to the Callahan Divide physiographic province, where the more marine components of the Fredericksburg rest on the Antlers Formation, and the classic Walnut and Comanche Peak of the Lampasas Cut Plain cannot be differentiated (Moore, 1969, p. 9). Therefore the 80-foot section southwest of Abilene in the Callahan Divide region shares characteristics of both formations: fossiliferous, interstratified marl and nodular limestone (Moore, 1969, p. 9). At that same locality the rudist-bearing Edwards consists of only one true rudist biostrome, the Skelly-Hobbs Rudist Complex, which reaches a maximum thickness of 15 feet and covers at least six square miles (E. Marcantel, 1969, p. 19-23). The carbonate components merge to the west to form the "Callahan Complex," a package of oolitic, pelletal grainstones, packstones, and fossiliferous wackestones. This asymmetrical lenticular mound coincides with the crest of the Concho Arch (Boutte, 1969, p. 40-43). The upper Fredericksburg section is thought to have been removed by erosion (Fig. 6), however final Fredericksburg history remains uncertain (Moore, 1969, p. 11; E. Marcantel, 1969, p. 34).

WEST TEXAS

Westward, into the physiographic area of the Llano Estacado, Fredericksburg rocks thicken from 90 to 140 feet and are represented by thin Walnut, thick Comanche Peak, and thin Edwards units (Corwin, 1982, p. 52). Rudist mounds are again representative of the Edwards section. Disconformably underlying this group is the Antlers of the Trinity Group (Corwin, 1982, p. 17). The overlying contact is unconformable with a caliche horizon of the parent Miocene-Pliocene Ogallala Formation (Corwin, 1982, p. 20).

Further westward in the Stockton Plateau-Big Bend region, the Fredericksburg facies resemble tidal flat, rudist mound, and near-shore shelf facies of the Edwards Plateau (Scott and Kidson, 1977, p. 173).

MEXICO

Fredericksburg rocks in Mexico have been correlated with Fredericksburg and Early Washita equivalents in Texas (Fig. 6). The Aurora Limestone of the Rio Conchos area (Stephenson, 1942, p. 448) and the El Abra, Tamaulipas, and Tamambras Formations of the Golden Lane-Poza Rica trend (Coogan et al., 1972, p. 1445) possess lithologic and faunal characteristics similar to those of the Stuart City Reef trend.

NORTH AMERICAN INTERIOR

Fredericksburg strata preserve their terminology within the interior of the continent in southwest Oklahoma, southwest Arkansas, and at the head of the Mississippi Embayment, in Missouri, Kentucky, and Illinois (Stephenson, 1942, p. 448). In the southern margin of the Western Interior (Kansas and Oklahoma), Fredericksburg equivalents are the Cheyenne Sandstone and the lowermost Kiowa Shale (Fig. 6; Scott, 1970, p. 1235).

STRATIGRAPHY OF THE FREDERICKSBURG GROUP, EAST TEXAS BASIN

The stratigraphy of the Fredericksburg Group within the East Texas basin has traditionally been considered to consist of the Paluxy Sandstone, Walnut Clay, and Goodland Formations (from the base upwards). However, basin-wide electric log correlations reveal that this nomenclature needs some modification. The correlation of the Goodland Formation with areas to the south has long been debated; in this investigation, the Goodland is considered to be the time-equivalent of the Comanche Peak and Edwards Formations. Primary evidence for this is the similarity in lithology between the Goodland sequence and the Comanche Peak/Edwards overall sequence. Both exhibit similar outcrop lithologies, similar electric log signatures, a decrease in clastics, and an increase in carbonate content upward. The Edwards equivalent is more than 90 percent calcium carbonate. The Upper Fredericksburg section also exhibits gradual and consistent thinning to the north, thickening to the south, and thickening toward the Sabine Uplift (Figs. 12, 13, 14, 15, and 16). Therefore, for the remainder of this discussion, the term Goodland will be used only where the Edwards and Comanche Peak cannot be differentiated (Fig. 1). The Paluxy Formation merges with the Antlers Sands north of the Glen Rose pinchout, where the uppermost section of the Antlers Sands is the lateral equivalent of the Paluxy (Fig. 1). The basis for this division of the Antlers will be discussed later in the text.

FREDERICKSBURG GROUP

Lithology

Although the Fredericksburg strata vary within the East Texas basin, the group is always recognized on electric logs by a significant decrease in resistivity upward at the lower boundary and an upward decrease in spontaneous potential (SP) at the upper boundary. The lowermost contact is drawn at the top of the Glen Rose Limestone. The upper contact (Kiamichi-Goodland and Kiamichi-Edwards) is considered to be the resistant limestone directly below a thin shale (Fig. 17). The section consists predominantly of clastics in the north and carbonates in the south.

Contact Relationships

Gradational contacts are present between the Antlers and Paluxy Formations in the northern basin and the Glen Rose and Walnut Formations in the southern basin. Unconformable upper contacts may exist between the Edwards and Kiamichi Formations and the Goodland and Kiamichi Formations. The apparent nondepositional nature of the upper contact is discussed later in the text.

Distribution and Thickness

The Fredericksburg isopach map illustrates a general south to southeast thickening trend (Fig. 18). Most anomalous thicknesses are associated with known local

structural features. Thickening in the northeastern portion, Area A, coincides with the Cass Syncline. Central Basin thickening, Area B, lies within the Salt Province. Prominent thick sections in Areas C and D correlate with the Mexia-Talco fault system. More closely spaced contour intervals in Area E, reflecting a greatly increased thickening rate, are south of the Angelina-Caldwell Flexure, the Cretaceous shelf margin. This is accompanied by the increase of carbonates in the Stuart City Reef trend. The north-central basin, Area F, lacks local structural features. Thickening and related sand increase is attributed to the proximity of clastic sources. The unusual thinning, encircled by a thickening trend, on the Sabine Uplift (Area G) is due to later erosional truncation.

PALUXY FORMATION

Lithology

The lowermost Paluxy Sand, in outcrop, is medium to very fine sand, coarse silt, and clay (Owen, 1979, p. 12-13; Corwin, 1982, p. 29-31). On electric logs it is recognized as a sand-shale package between two limestone units over most of the basin (Fig. 19). Due to the northward merger into the Antlers and southward pinchout of the Paluxy, the contacts vary in the subsurface.

In the northern basin, beyond the Glen Rose pinchout (Fig. 1), the uppermost Antlers (Paluxy equivalent) is distinguished from the lower Antlers section by an abrupt, traceable change in electric log signature. The upper section is characterized by stacked sand bodies, whereas the lower section is shale-dominated with intermittent sand stringers, displaying very little response on either spontaneous potential or resistivity (Fig. 19). Apparently, this reflects a significant change in depositional history. It seems a logical division, in that the upper Antlers section is correlative with similar stacked sands of the laterally adjacent Paluxy Formation. The thicker, upper Antlers section (Paluxy equivalent) represents a prolonged period of fluvial-delta deposition during a regressive and transgressive episode (for more detailed evidence, refer to summary figure caption, Fig. 34). Although the depositional contact is within the stacked sand section rather than at the base, for purposes of mapping, and because of accepted nomenclature, the lower boundary is shown at the base of the stacked sands at a small, persistent resistivity feature in the form of a groove or a notch. The upper contact is placed between the uppermost Paluxy Sand and the thin Walnut Limestone or Shale (Fig. 19).

In the southern basin, where the Glen Rose is present (Fig. 1), the base of the Paluxy is indicated by high resistivity at the top of the Glen Rose Limestone. The upper contact is placed at the base of the Middle Walnut member for consistency, because uppermost Paluxy lithology varies from thin shales to sand stringers to

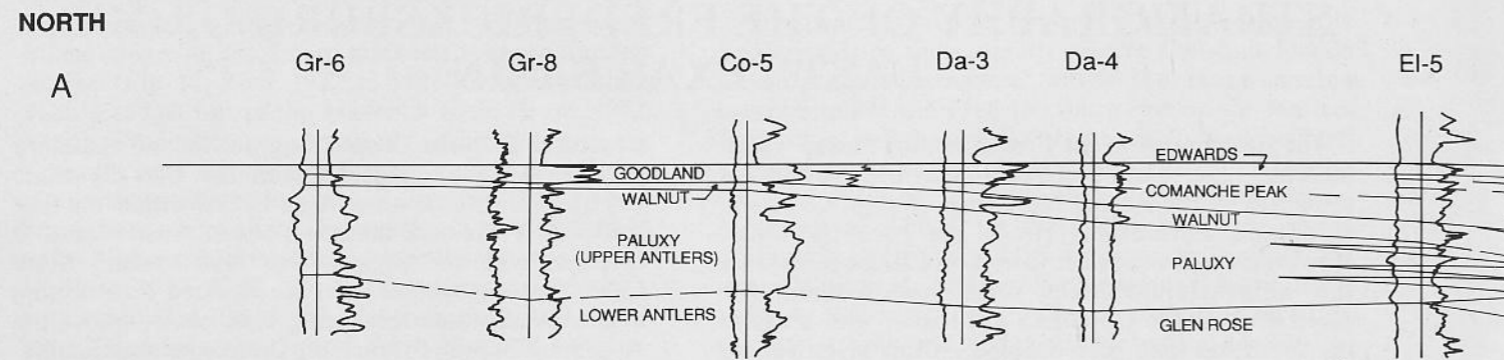


Fig. 12. North to south stratigraphic cross section A-A' (see Fig. 5).

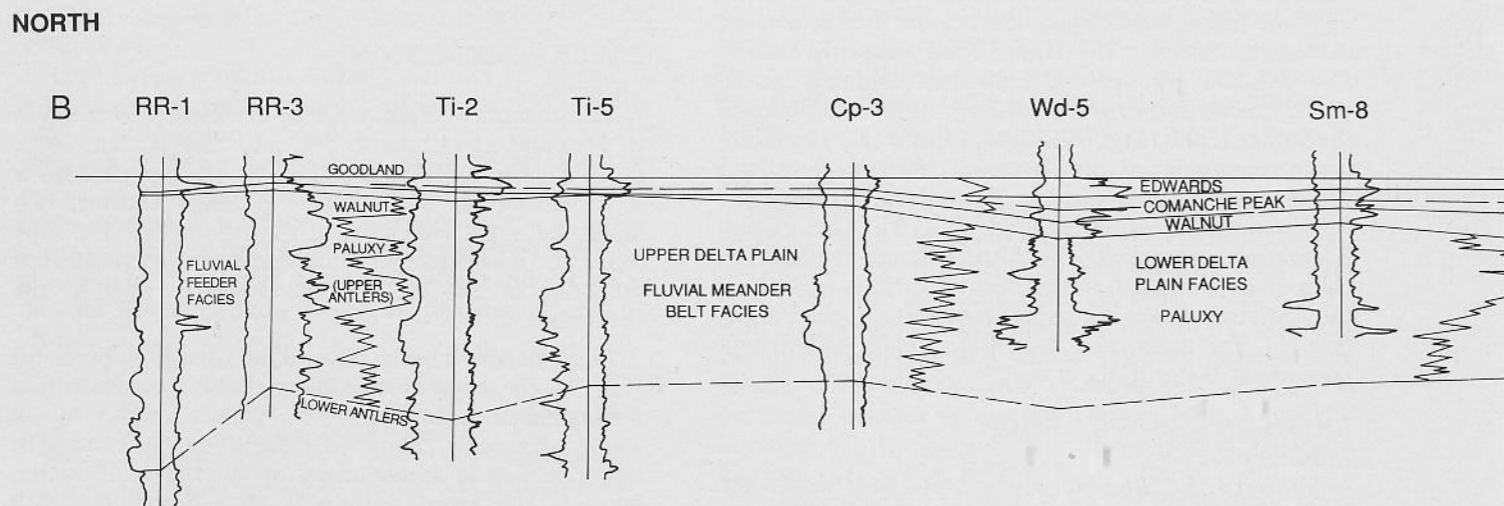


Fig. 13. North to south stratigraphic cross section B-B' (see Fig. 5).

blocky sands. The contact is drawn where the ragged signature of uppermost Paluxy terminates upwards against a high resistive signature, characteristic of the Walnut Limestone middle member (Fig. 19).

Contact Relationships

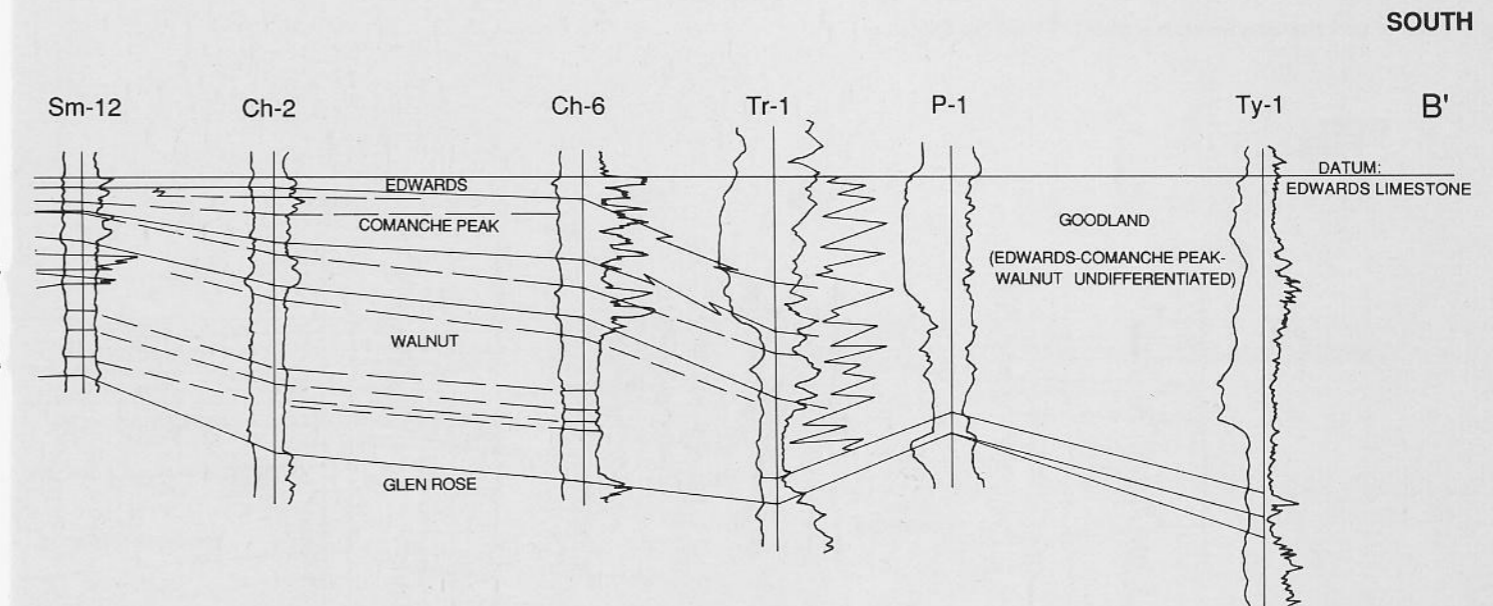
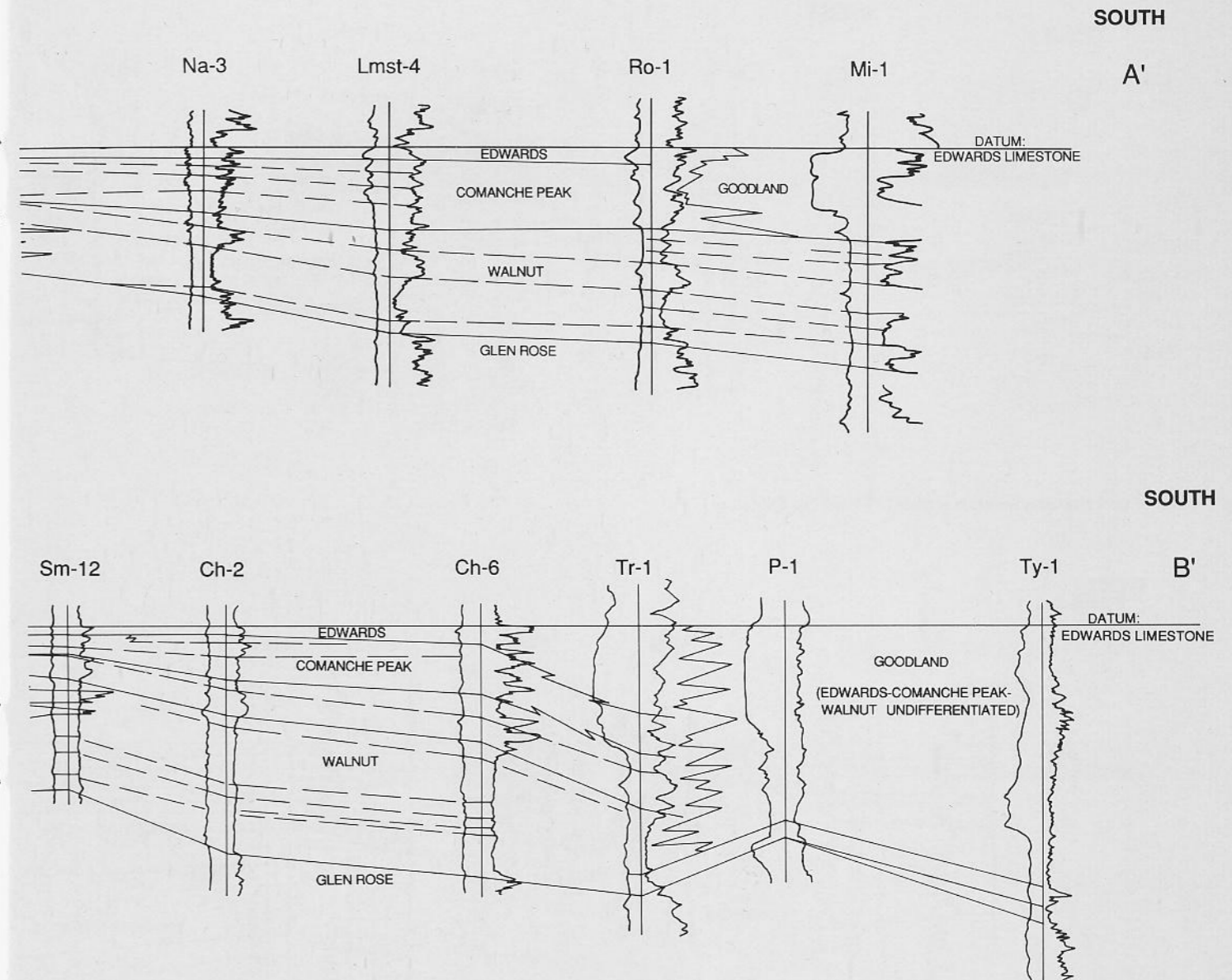
In surface exposures, the basal contact with the Glen Rose Limestone is generally conformable and may be abrupt, gradational, or interfingering (Owen, 1979, p. 9). The Paluxy-Walnut contact is generally conformable (Flatt, 1975, p. 12). Localized areas with moderately dipping Paluxy beds overlain by horizontal Walnut Shale beds have been interpreted as unconformable (Owen, 1979, p. 12). This angular relationship of beds was believed to represent a gentle onlapping of marine Walnut sediments onto periodically exposed and cemented Paluxy strandline deposits (Moore and Martin, 1966, p. 982-985). I offer a different interpretation of the localized phenomena, that they reflect a slow and gentle migration of basinal facies (Walnut

Shale) over nearshore facies (Paluxy Sand) with no hiatus period, thus no unconformity. In the subsurface, the gradational nature of the log response reflects the generally conformable upper and lower contacts (Fig. 19).

Distribution and Thickness

The basal Paluxy Formation is present only in the northern portion of the basin (Fig. 20). The relatively thin wedge of sandstone and shale thins uniformly to the south, apparently a product of distance from sources to the north (Figs. 12 and 13). The zero contour represents the sand pinchout and the final line of facies intergradation with the basinal equivalent Walnut Clay facies (Figs. 12, 13, and 20).

Regional thickening is to the east. Local accumulations occur along the margins, and in the center region of the basin. The protruding lobes of Areas A, B, and C suggest sediment input points from the north, west, and northwest. Branching from the eastern border in



Area D is an east-west trend coinciding with the Cass Syncline. The thickness of 450 feet is a product of thick shales rather than the stacked sand sequences of the lobes (Fig. 14). Maximum thicknesses of 600-650 feet are associated with structural features within the central basin area. Correlations between the elongated thick section in Area E and the northern Mexia-Talco fault system are exact, suggesting contemporaneous fault activity with deposition. The depocenter in Area F lies within the Salt Province, indicating salt activity during Paluxy deposition.

A sand isolith map illustrates the nature of deposition (Fig. 21). Eight input points are delineated in Areas A and B, as indicated by arrows. Those fluvial systems of Area B coincide with paleodrainageways and are in accord with field evidence (Brothers, 1984, p. 21-23, Plate II). The merger of these systems with those of Area A and the predominant north-south trend of the conduits suggest that the major source area was to the north. Widespread dispersal in Area C conforms to the

configuration of a lobate delta complex. Drastic variations in sand thickness of Area C reflect salt movement. Thinning of the Paluxy over the Van, Hawkins, and Hainesville anticlines (shown by pattern in Area C) is due primarily to nondeposition during anticline growth (Seni, 1981b, p. 53). Two anomalous elongate thicks in Area D may be offshore bars (Fig. 15), though orientation is impossible to determine due to the paucity of well control. The overall north-south geometry of sand distribution and lack of east-west coalescing sand bodies indicate a constructive fluvial-deltaic complex with very low tidal action and wave energy.

WALNUT FORMATION

Lithology

The basal unit of the Fredericksburg in the southern study area is the Walnut Clay. The five-member formation consists of a basal limestone, thick lower clay, two middle limestones, and thick upper marl units

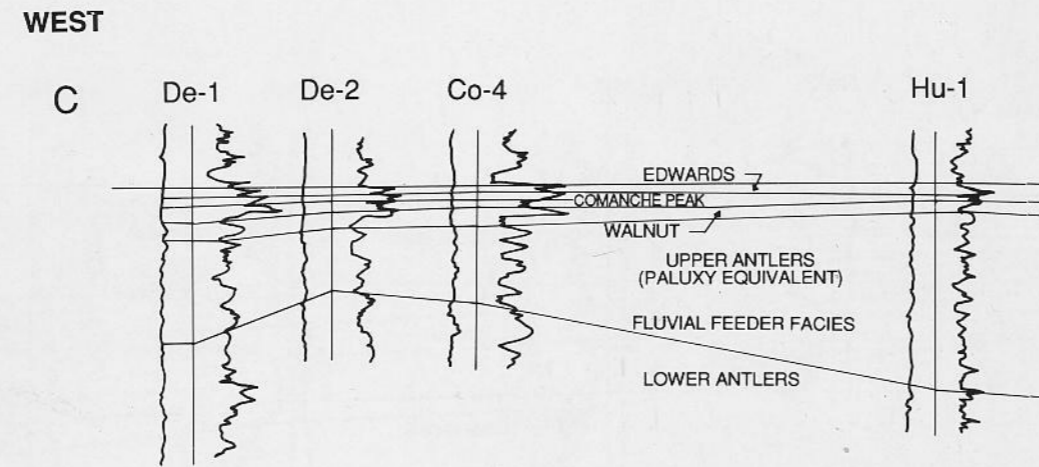


Fig. 14. East to west stratigraphic cross section C-C' (see Fig. 5).

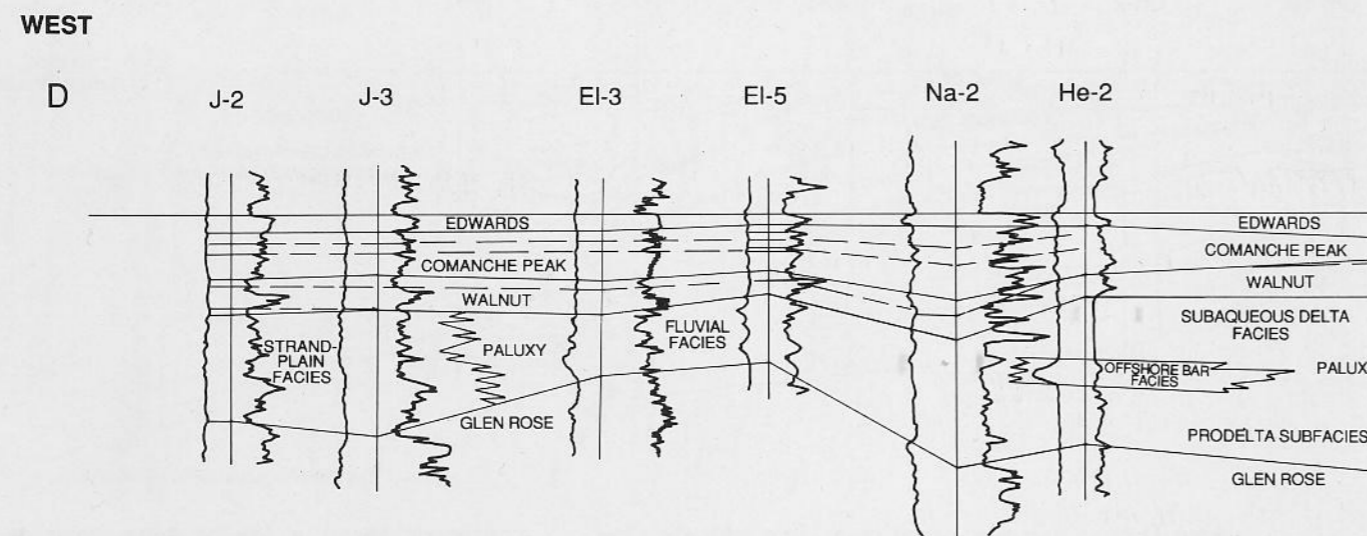


Fig. 15. East to west stratigraphic cross section D-D' (see Fig. 5).

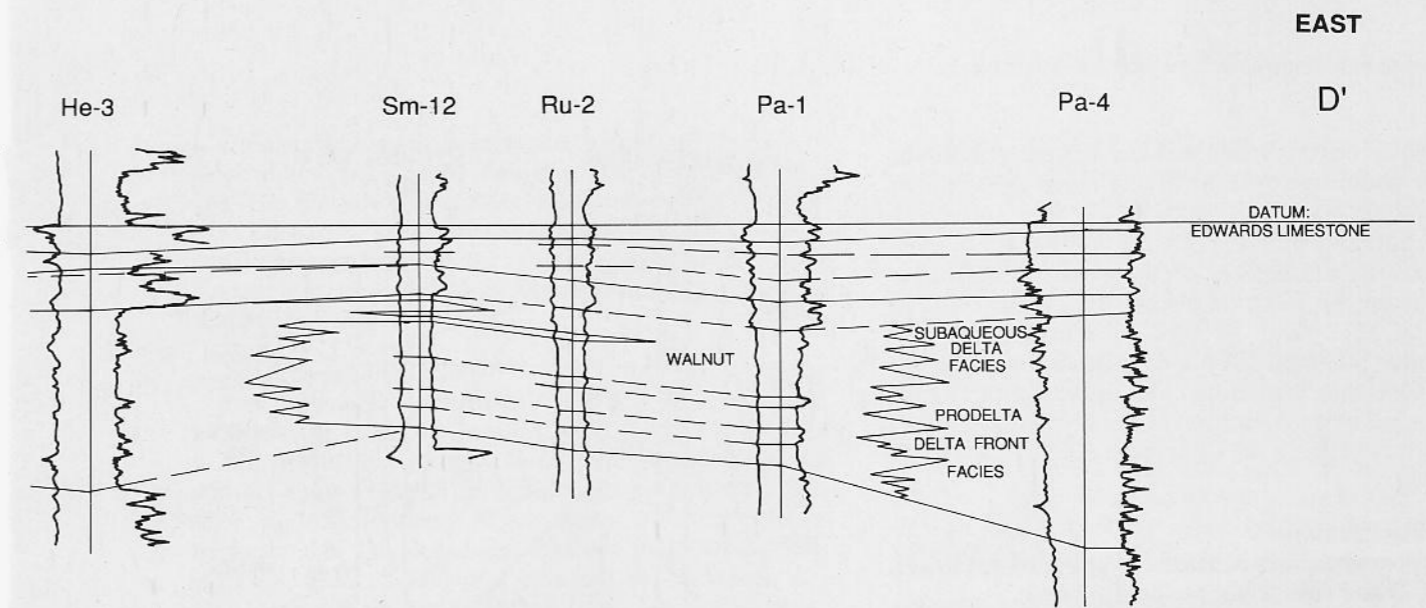
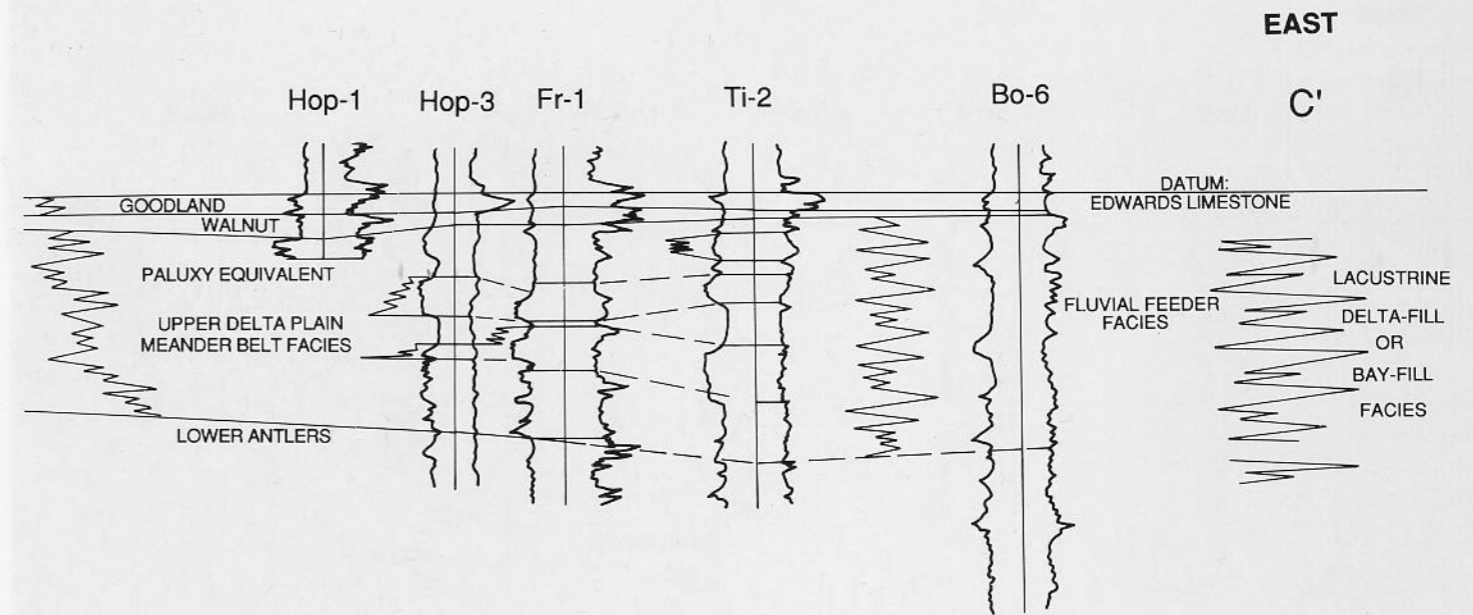
(Moore and Martin, 1966, p. 984). Both limestone and clay intervals have characteristic *Texigrypha* and *Exogyra* oyster banks (Flatt, 1975, p. 16). The base of the Walnut contains only small amounts of reworked Paluxy quartz sand (Flatt, 1975, p. 12).

The five members can be traced into the subsurface and recognized on electric logs as two limestone units separated by thick marl-shale sections (Fig. 22). Where Paluxy Sand is absent (Fig. 8), the lower contact is placed between the Glen Rose Limestone and the basal Walnut Limestone. The lower contact is drawn at the base of the middle limestone where Paluxy Sand is present (Fig. 8). The upper contact separates the lower, shale-dominated Walnut from the upper, carbonate-dominated Comanche Peak. The top of the Walnut is marked at the point of increase in both spontaneous

potential (SP) and resistivity reflecting a change from shale to limestone (Fig. 22).

Contact Relationships

The overlying Walnut is considered conformable and unconformable with the basal Paluxy (Flatt, 1975, p. 12; Owen, 1979, p. 9, 12). On outcrop, the angular relationship between the Paluxy and Walnut has been cited as the basis for recognition of the unconformity. However, I believe deposition was continuous with a migration of basinal facies over strandline deposits. An interfingering relationship also exists between the Walnut and the Paluxy (Figs. 12 and 13). A conformable and gradational contact separates the Walnut and overlying Comanche Peak Formations (Flatt, 1975, p. 12; Keyes, 1977, p. 29). In the subsurface, gradational



electric log responses suggest conformable upper and lower contacts (Fig. 24).

Thickness and Distribution

The Walnut Formation occurs throughout the basin (Fig. 23). Regional thickness ranges from less than 50 feet in the north to 550 feet in the south. Of the five members, only the middle limestone is laterally extensive throughout the basin, thickening uniformly to the south (Figs. 12, 13, 14, 15, and 16).

The maximum thickness in Area A coincides with the southernmost region of the Salt Province and the southern perimeter of the Mexia-Talco system. Thickening takes place principally in the lower clay unit (Figs. 12 and 16), indicating both salt and fault movement during Early Walnut deposition. Accumu-

lations on the Sabine Uplift, Area B, are attributed to thickening of the middle limestone unit (Fig. 15), possibly a facies correlative with a structural high or a more rapidly subsiding area. Broad thinning in Area C follows the trend of the Stuart City Reef, suggesting that it was a paleotopographic high. The rapid thickening of the Walnut south of the 50-foot contour does not indicate a shelf slope, but the gradational interfingering relationship with the Paluxy Sand. The basal Walnut Members were deposited contemporaneously with the Paluxy Sands.

COMANCHE PEAK FORMATION

Lithology

Comanche Peak surface exposures consist of interstratified nodular limestone and marl (Keyes, 1977, p. 19). The overall upward sequence represents a transition

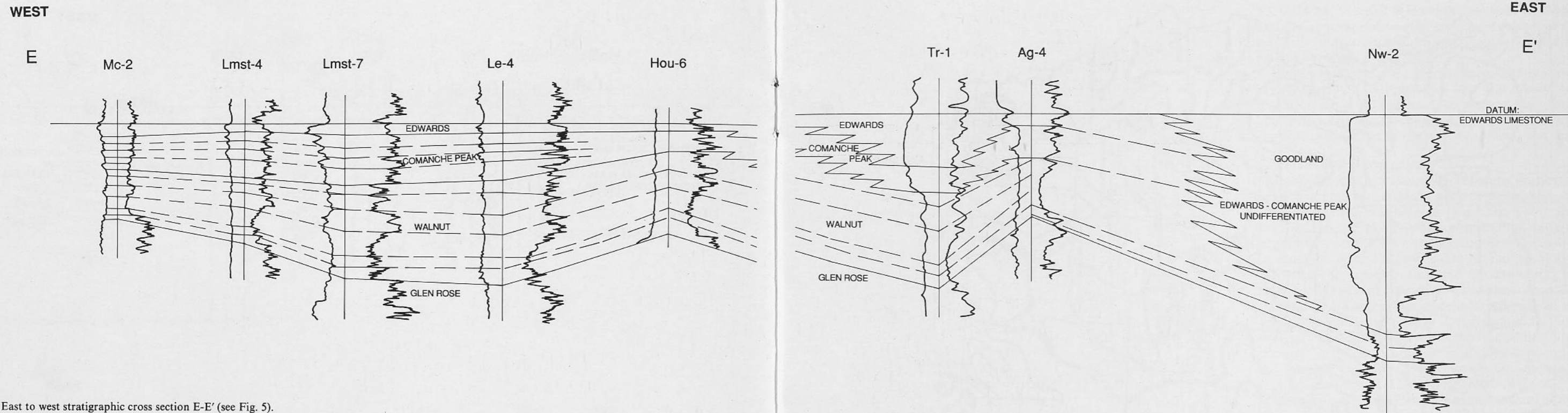


Fig. 16. East to west stratigraphic cross section E-E' (see Fig. 5).

from slightly brackish and normal marine conditions to marine conditions with little clay input to the upper Fredericksburg section (Keyes, 1977, p. 48).

The remarkably uniform lithological character can be traced into the subsurface, allowing easy identification of the Comanche Peak on electric logs (Fig. 24). The base is at the point of upward increase in both spontaneous potential (SP) and resistivity marking the shale-to-limestone transition. The upper contact is the point of rapid upward decrease of resistivity representing the boundary between the Comanche Peak and Edwards Limestones.

Contact Relationships

Both upper and lower contacts in both outcrop (Keyes, 1977, p. 52) and subsurface are conformable.

Thickness and Distribution

The Comanche Peak Formation is a distinct unit throughout the central basin (Fig. 25). The formation merges with the Edwards to form the Goodland to the north and to the south (Figs. 12 and 13). The unit exhibits a general thickening to the south towards the Stuart City Reef trend. The prominent thick area (Area A, Fig. 25), roughly coincides with thick Walnut (Area A, Fig. 23), possibly indicating a continuation of fault movement and salt withdrawal.

EDWARDS FORMATION

Lithology

The Edwards Formation in outcrop is a rudist-bearing carbonate unit which lacks terrigenous material (Corwin, 1982, p. 49).

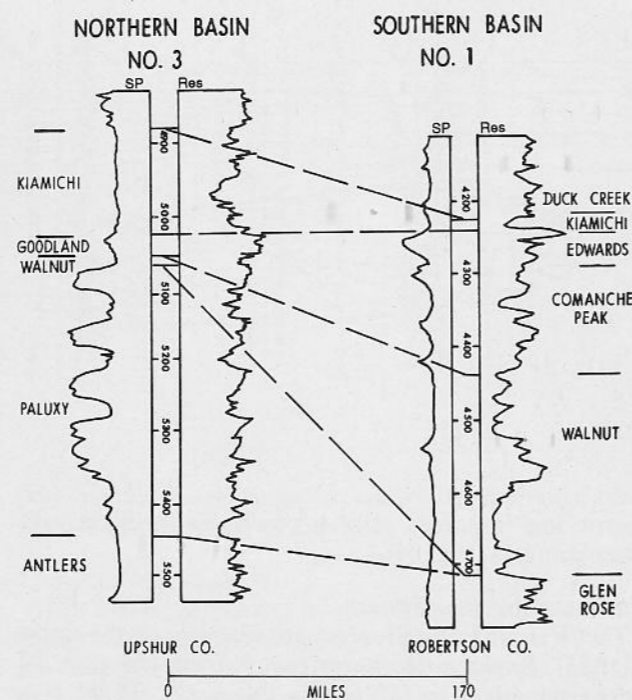


Fig. 17. Electric log signatures of the Fredericksburg Group characterizing the northern clastic-dominated basin and the southern limestone-dominated basin. Gradational log responses with the Glen Rose suggest conformable or disconformable lower contacts. Abrupt changes in signatures between Edwards and Kiamichi and Goodland and Kiamichi suggest a possible unconformable contact or abrupt change in depositional environments. The contacts between the Fredericksburg formations apparently reflect gradational and conformable contacts.

On electric logs, it is seen as a persistent, 20-25-foot thick limestone directly below a thin shale unit (Fig. 26). The marked upward decrease in resistivity between the Edwards and Comanche Peak Limestone is considered to be the base of the Edwards. The upper contact is at the top of the strong response in spontaneous potential or resistivity.

Contact Relationships

The Edwards conformably overlies the Comanche Peak on the surface (Corwin, 1982, p. 19, 25, 34) and in the subsurface. Exposures of the Edwards-Kiamichi contact show evidence of minor unconformity (Bishop, 1967, p. 163). Evidence of an unconformity also exists between the Edwards and Duck Creek Formations (Corwin, 1982, p. 39) and between the Edwards and Del Rio in West Texas (Brian Lock, April 7, 1987—personal communication). The unconformities discussed here are nondepositional, characterized by case hardening, oxidation, borings, and pits in the upper surface of the Edwards Formation. On the basis of personal observations, I believe that this widespread phenomenon represents a submarine nondepositional surface. It is possible that this unconformable relationship persists into the subsurface, where similar thicknesses and character mark the formations.

Thickness and Distribution

The most striking feature of the Edwards isopach is the constant thickness of 20-25 feet throughout the greater part of the basin (Fig. 27). Marginal accumulations of 50-100 feet border the area on the east and south. For the most part, the massive limestone thicks

are related to structural features and areas of greater subsidence. In the northeast, Area A, limestone gradually thickens to undifferentiated Goodland. The Sabine Uplift, Area B, lies directly south of the Cass Syncline. The inconspicuous thick at B' implies thickening towards the Edwards-Goodland intercalation zone. The same holds true to the southwest in Area C. Region D, with a thickness of 50 feet, may be related to contemporaneous faulting of the Mexia system as in Areas A on the Walnut and Comanche Peak isopach maps (Figs. 23 and 24); or may be a possible carbonate buildup similar to that of reefal mounds in nearby outcrop exposures. The Moffat Lentil, Area E, attains a maximum thickness of 125 feet, apparently a reef buildup over the Belton High (Kerr, 1977, p. 217).

GOODLAND FORMATION

Lithology

In outcrop, the Goodland Formation consists of alternating marls and fossiliferous limestones, with an overall upward increase in massive bedded limestone and decrease in marls (Staples, 1977, p. 49). The electric log response is characterized by a strong resistivity response documenting the transition from a shale into a limestone (Fig. 28).

Contact Relationships

The Goodland-Walnut contact varies from sharp to gradational (Staples, 1977, p. 19). Evidence for an unconformity between the Goodland and the Kiamichi is similar to that described for the Edwards-Kiamichi unconformity. Reports of Kiamichi-filled borings in the top of the Goodland (Laali, 1973, p. 88-120; Localities

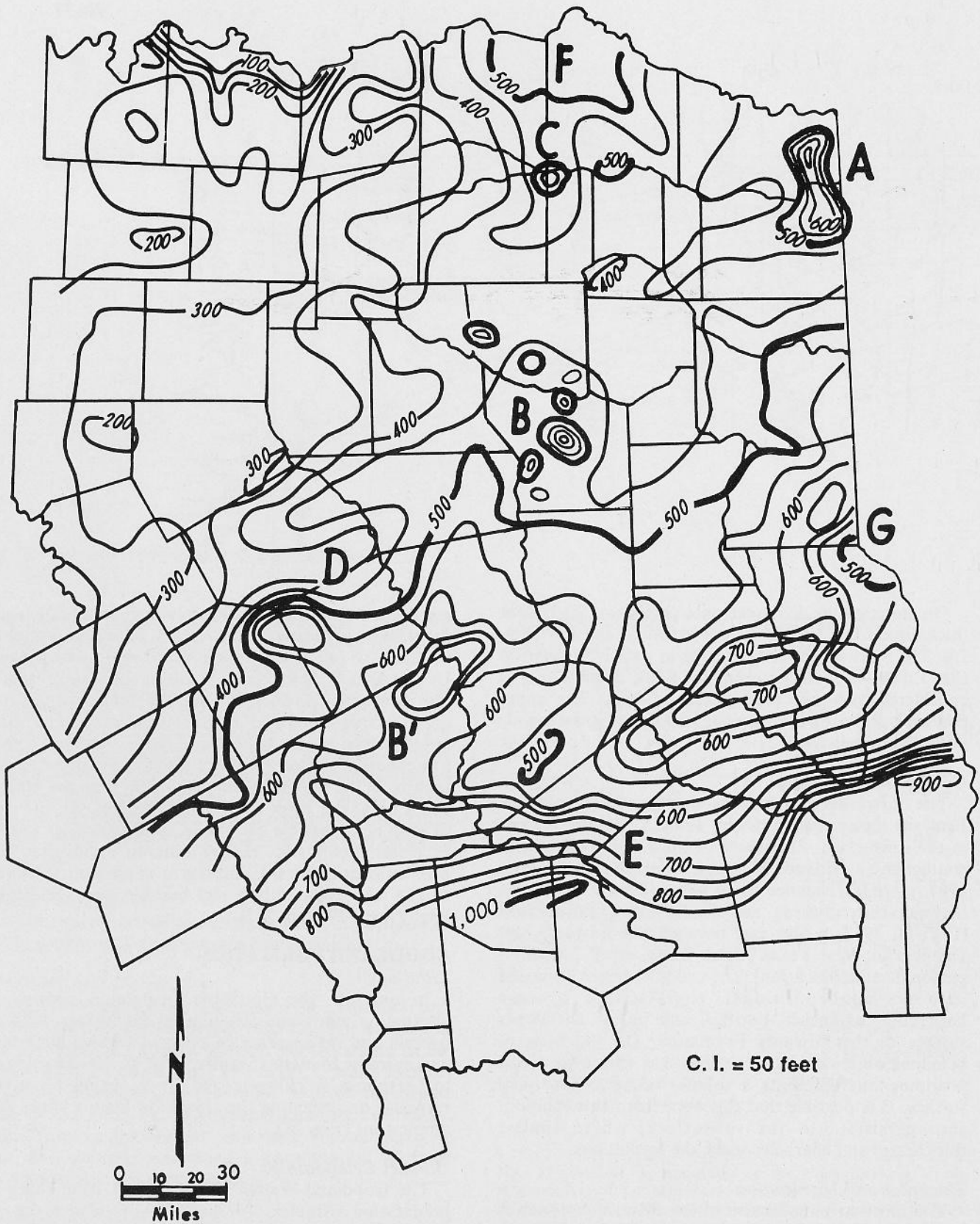


Fig. 18. Isopach of the Fredericksburg Group. Thickening is to the south-southeast. Anomalous thicknesses result from local structural activity.

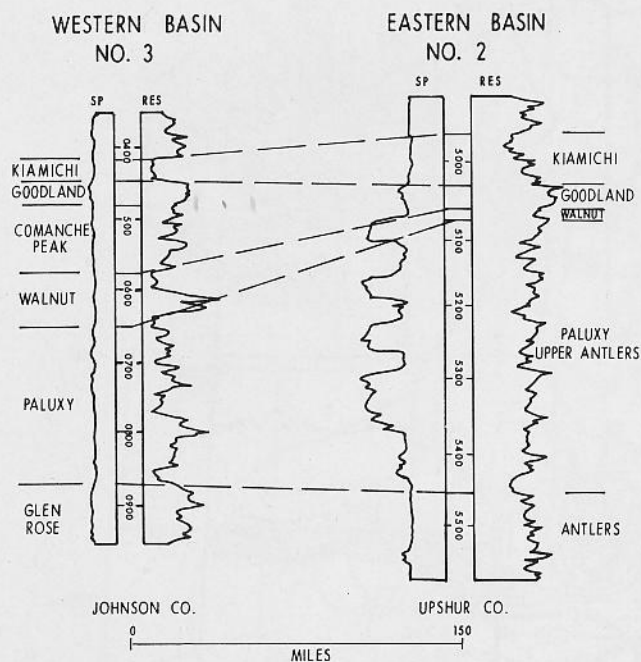


Fig. 19. Electric log signatures of the Upper Antlers Formation (Paluxy equivalent) of the eastern basin and the Paluxy Formation of the western basin. The Upper Antlers is differentiated from the Lower Antlers by significant changes in electric log signatures. The Upper Antlers is characterized by stacked sand bodies ranging in thickness from 20 to 150 feet, averaging 40 feet. The Lower Antlers consists of thin alternating beds of shales and sand stringers.

T3, G1, Ch1, M1, and W1) were confirmed. It is believed that the upper surface can be correlated to that of upper Edwards, suggesting a widespread submarine nondepositional surface.

In the subsurface, the lower contacts of the formation are gradational. Upper contacts are likely to be unconformable, as indicated by electric log character and the similarity in outcrop and subsurface thicknesses. However, the nature of the upper contact is not certain.

Thickness and Distribution

Two conspicuous east-west bands along the north and south margins of the study area contain most of the Goodland rocks encountered (Fig. 29). The northern strip, strip A, averaging 30 feet, also contains anomalous 60-80-foot thicks in the northwest corner. Lobes similar to those of A' and A'' probably extend all along the feather edge, representing the intertonguing zone between Goodland and time-equivalent formations. Paucity of well control limits delineation of those lobes. The gradational zone of strip B, represented by the zero contour line, coincides with the Angelina-Caldwell Flexure. A maximum thickness of 1060 feet occurs in the Humble Ogletree #1 well, and correlates with the axis of the Stuart City Reef trend (Fig. 29); axis orientation was delineated by seismic control. Area B', associated with the Sabine Uplift, shows thinning to the east, apparently due to post-Comanchean erosional truncation (Halbouty and Halbouty, 1982, p. 1064; Scott, 1970, p. 525; Granata, 1963, p. 75). The complexity of stratigraphy on the Sabine Uplift within the vicinity of B' increases with the gradational change into the massive Goodland Formation (Fig. 13).

DEPOSITIONAL HISTORY OF FREDERICKSBURG GROUP, EAST TEXAS BASIN

INTRODUCTION

Discussion in this section first highlights the depositional history of the pre-Fredericksburg in the East Texas basin. Attention then shifts to the regional depositional history on the Comanchean shelf, and then to the depositional history of the Fredericksburg in the East Texas basin. Although the histories of the shelf and basin were contemporaneous, they are treated individually due to lack of clear time-lines. Discussion begins with the initial clastics of the Paluxy Formation and the advent of Walnut Formation carbonates. The history then traces the continual carbonate deposition during Comanche Peak time through the culmination of carbonate deposition during Edwards time. The end of Fredericksburg time with Kiamichi deposition is also discussed. A summary of Fredericksburg history is illustrated in a series of sequential facies distribution maps within the East Texas basin (Figs. 30 through 37).

Identical facies geometry may result from a combi-

nation of processes: sedimentation, eustacy, and subsidence. Because of their interdependence, it is frequently difficult to divorce one from the others as a primary cause.

The East Texas basin is, by definition, a young continental margin shelf, its origin due to the regional rifting that opened the Gulf of Mexico (Wood and Walper, 1974, p. 40-41; Van Siclen, 1983, p. 239). Shelf subsidence, said to be a result of lithospheric cooling away from the spreading axis, is the predominant tectonic activity of young continental margins (Bott, 1971, p. 319-327). The cooling process persists long after initial separation and declines exponentially with time (Bott, 1971, p. 319-327). Thus, the transgressive nature of the Fredericksburg may be explained by subsidence alone, and eustatic sea level changes may be of minor importance, except for the possible sea level rise at the beginning of Edwards time. Sediment loading was only a minor contributor to subsidence.

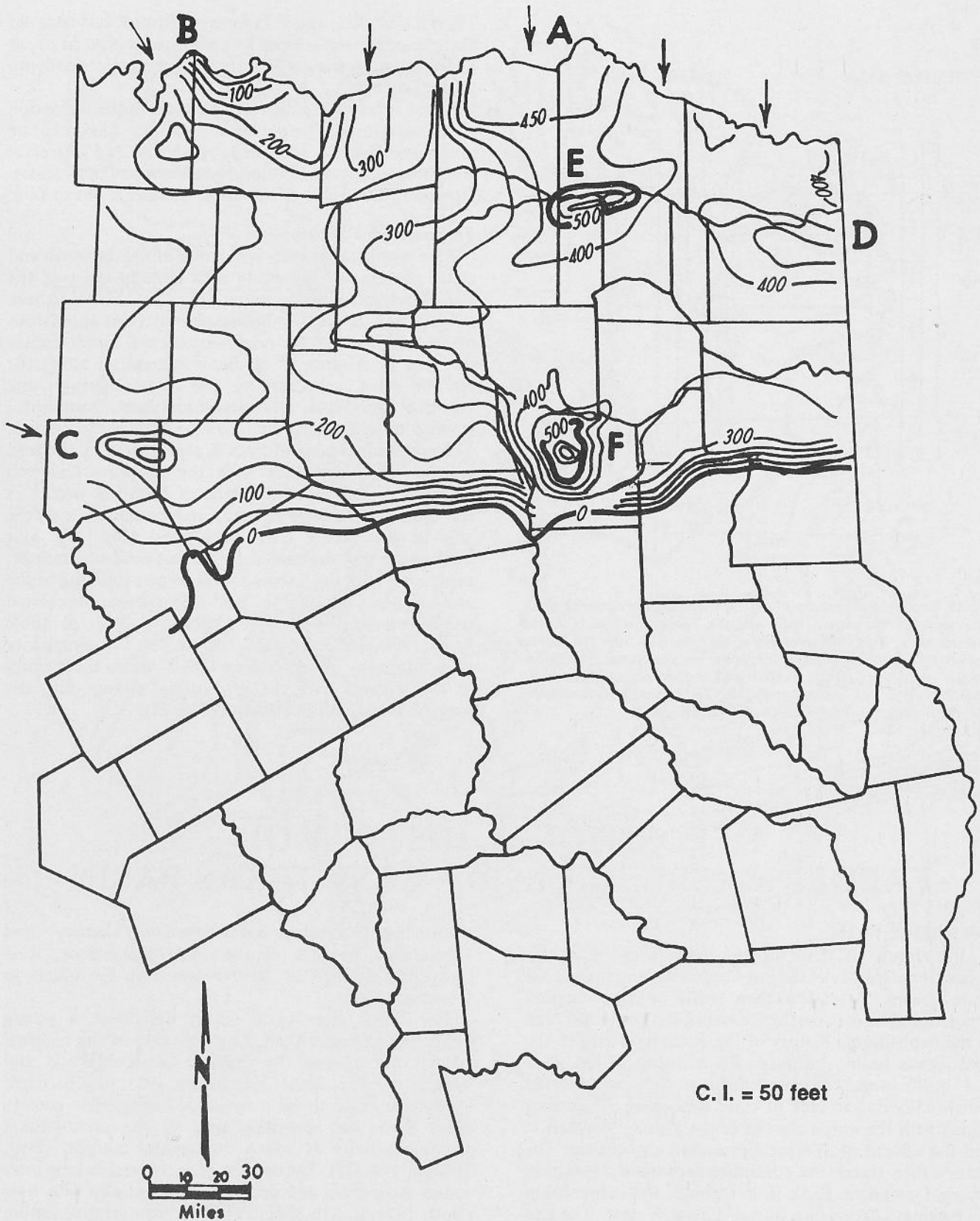


Fig. 20. Isopach of the Paluxy Formation. The southern termination of the clastic unit is near the center of the basin (Figs. 7 and 8). Thickened strata in Areas A, B, and C suggest clastics entered the basin from the north and northwest. The band of closely spaced parallel contours near the pinchout represents a gradational zone with the time-equivalent Walnut basinal facies and has no major structural significance. The zero contour marks the limit of sand deposition in the Paluxy/Walnut facies complex. Walnut Clay was deposited to the south while Paluxy Sand was deposited to the north.

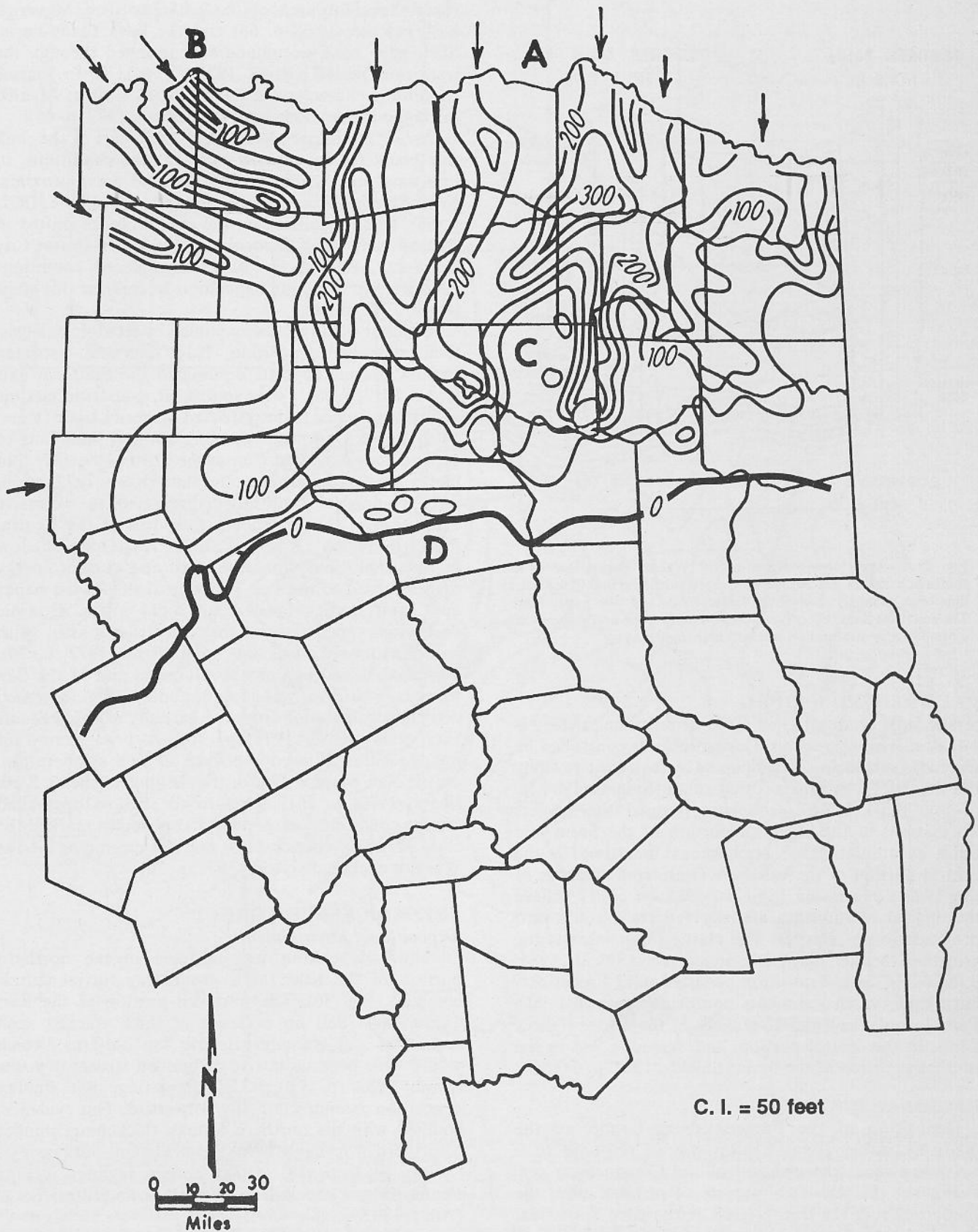


Fig. 21. Isolith of the Paluxy Formation. Predominant north-south sand geometry reflects a constructive, river-dominated fluvial-deltaic system. Input points are indicated by the arrows. Note particularly the salt structures near letter C (shown as closed circles), interpreted as positive features, which affected Paluxy deposition. Ellipses near letter D are interpreted as offshore bars.

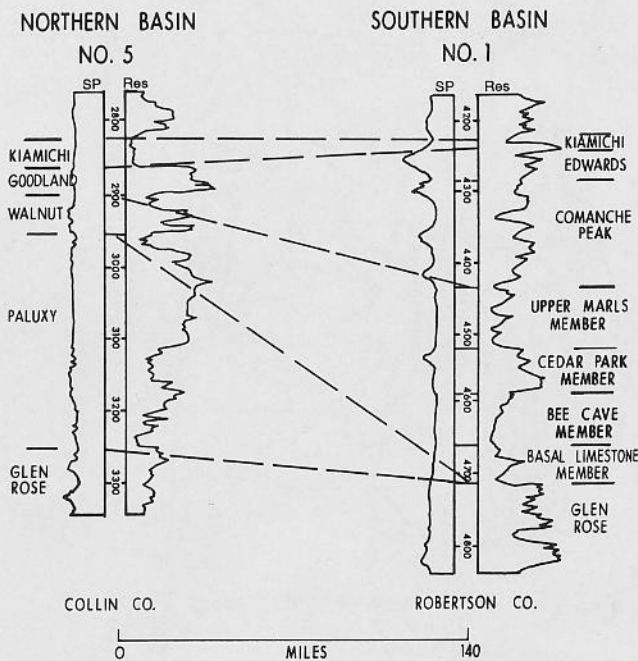


Fig. 22. Electric log signatures of the Walnut Formation. In the southern basin, all five members are represented: the Bull Creek (basal limestone member), Bee Cave, Cedar Park, and two upper marls. The limestone units reflect significant thinning to the north, apparently a product of sedimentation rate and bathymetry.

PRE-FREDERICKSBURG

The final phase of Glen Rose depositional history is one of marine regression. Deposition was controlled by increased subsidence accompanied by fault activity along the Balcones and Mexia-Talco zones (Shields, 1984, p. 63-64). Thick clastic sequences (termed the Antlers Formation) in the northern portion of the basin and thick accumulation of argillaceous limestone in the central portion of the basin are considered evidence of the Trinity regression (Shields, 1984, p. 63). I believe this lateral relationship actually reflects a southward progradation of clastics. The clastic input inhibits the growth of the shelf margin carbonate reefs (Shields, 1984, p. 53-64). Clastic deposition persisted until Fredericksburg time, when sediments conformably graded into Paluxy equivalent (Antlers) sands in the north, Paluxy Sands in the central portion, and Walnut Clays in the southern portion of the basin (Shields, 1984, p. 64).

REGIONAL HISTORY

Deposition of the Fredericksburg Group on the relatively stable Texas Craton was in response to a northwestward transgression of the Comanchean sea. Following the late Trinity cycle of progradation, the Fredericksburg sea transgressed across Glen Rose tidal flats and other marginal marine deposits, which were slightly eroded (Rose, 1972, p. 66). A gradational boundary is more representative of Glen Rose-Fredericksburg transition in the slightly deeper or more

rapidly subsiding areas of the Comanche Shelf (Maverick basin) (Rose, 1972, p. 66) and the East Texas basin. Shelf edge bank accumulation continued through the transition period (Rose, 1972, p. 66). Open marine conditions characterized the ancestral Gulf of Mexico throughout Fredericksburg time (Rose, 1972, p. 66).

During the initial phase, the greater part of the shelf was blanketed by shallow open marine conditions, of low wave and current energy. Isolated areas proximal to positive features received sands and silts (Rose, 1972, p. 66). Upon stabilization, the environments shifted to shallow-water shelf deposition protected by Stuart City carbonate reefs. A few areas experienced conditions conducive to dolomite deposition as early as this stage (Rose, 1972, p. 66).

Regional shoaling, accompanied by tectonic changes, then controlled deposition. Tidal flats and restricted shallow marine deposits dominated the Platform axis (Rose, 1972, p. 66). To the southwest, evaporitic, euxinic conditions existed in the restricted Maverick basin (Rose, 1972, p. 66). Continued shoaling allowed tidal flats to expand across the vast Comanche Shelf and evolve into highly evaporitic, sabkha tidal flats (Rose, 1972, p. 66-70). Evaporitic conditions culminated in extensive deposition of the Kirschberg Evaporite in the Central Platform region (Rose, 1972, p. 70). Open shallow marine conditions with low wave and current energy then returned to the vast platform shelf. Rudist banks and sand bodies existed on local highs. Euxinic conditions persisted in the Maverick basin, with accumulation of dark lime mud (Rose, 1972, p. 70). Increased subsidence on the southeast end of the San Marcos Platform was accommodated by increased detrital accumulation from the partially exposed Stuart City reefs (Rose, 1972, p. 70). A brief period of nondeposition allowed exposure, as well as alteration, on the San Marcos Platform axis and northeast flank (Rose, 1972, p. 70). A return to shallow open-shelf marine conditions on the vast, flat platform marked the close of the Fredericksburg and the beginning of the Washita deposition (Rose, 1972, p. 70).

FREDERICKSBURG GROUP

Depositional Environments

Paluxy deposition was initiated in the northern portion of the basin as a prograding fluvial deltaic complex (Fig. 36). The northern portion of the East Texas basin had no evidence of thick stacked sand sequences and irregular electric log patterns, which would have been indicative of braided stream deposits (Cant, 1982, p. 120, 131), suggesting that Paluxy deposition extended laterally northward. This evidence, coupled with the northern Paluxy thickening, implies a northern provenance in the Arbuckle-Ouachita systems (Atlee, 1962, p. 18). Other source regimes include Pennsylvanian and Paleozoic strata from central Texas (Atlee, 1962, p. 18).

The Paluxy complex rapidly invaded the basin as laterally migrating, constructive fluvial-deltaic systems. Fluvial-deltaic interpretation is supported by existence of abandoned channel fill, point bar, and interdistrib-

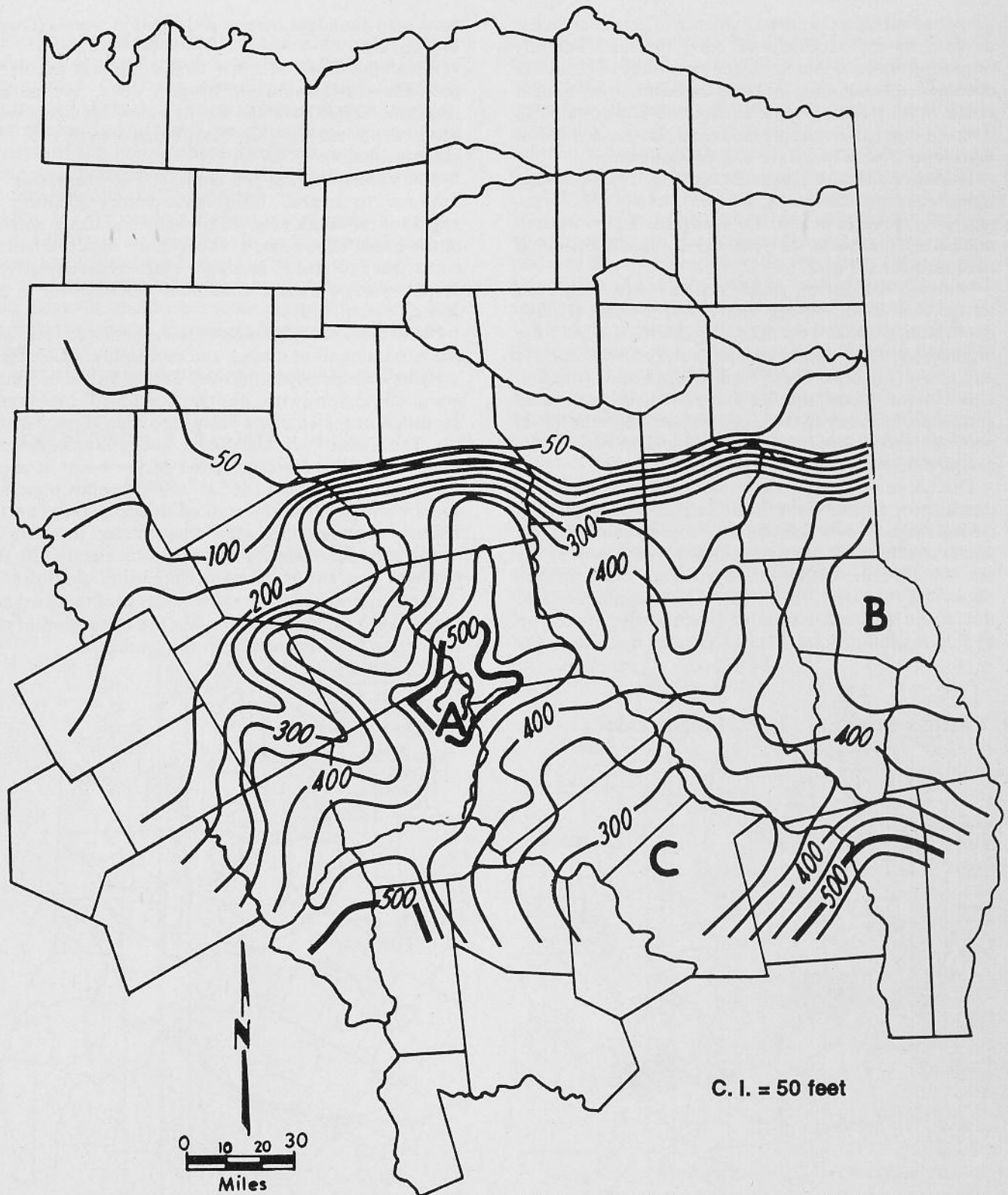


Fig. 23. Isopach of the Walnut Formation. Major Walnut deposition occurred in the southern basin contemporaneous with the Paluxy deposition to the north. The tightly contoured band near the basin center represents the gradational zone with the Paluxy Formation. The Walnut of the northern basin consists of less than 50 feet of limestones and clays, resting conformably upon a southward thinning Paluxy Formation. Thick Walnut accumulation in Area A coincides with the southernmost extent of the Salt Province, thus implying salt activity during early Fredericksburg deposition. Walnut thickness in Area B, the Sabine Uplift area, is due to one of two causes, both related to subsidence: (1) detritus accumulation; or (2) reefal accumulation because sedimentation rate matched the subsidence rate. The thinning in Area C, south of the Angelina-Caldwell Flexure, is the likely site of Glen Rose reef development, and indicates that Walnut deposits were draped over a paleotopographic high. The stacked contours at the northern limit are an artifact of the interpretation. South of the 50-foot contour there are no sands in the Walnut-Paluxy interval. North of this line, sands are increasingly abundant, and the section is called Paluxy.

utary bay subfacies in cores. Evidence of point bar facies, as seen in the McCrary #1 core, indicates laterally migrating systems, indicating the possibility of point bar development extending well into the basin. Predominant north-south trending sand distribution is attributed to river-dominated delta progradation across a shallow marine shelf with low wave and current energy.

During maximum progradation (Fig. 31), dominant input was from the north; however, minor tributaries, primarily from the central Texas region, fed the western margin of the basin, as reflected by thin lobed sand accumulations (Fig. 21).

Seaward advancing delta systems and continued terrigenous input during Early and Middle Paluxy deposition gradually changed deposition of Glen Rose argillaceous lime mud to accumulation of Walnut clays and marls (Fig. 32). These basal Walnut units (the Bull Creek Member and the Bee Cave Member), deposited contemporaneously in the southern portion of the basin, probably represent nearshore, brackish conditions, marginal to the Paluxy fluvial systems.

Discharge of upper Paluxy sediments into the basin diminished, to mark the beginning of Fredericksburg transgression. Slow subsidence, accompanied by the decrease of clastics, allowed gentle encroachment of the sea. Initial Fredericksburg transgression is delineated on Figure 32 (Owen, 1979, p. 22). This subtidal zone of fluvial and marine intercalation is represented in outcrop by thin fossiliferous sand beds separated by thicker clay

units with abundant oysters and serpulid worms (Owen, 1979, p. 29).

While Bee Cave Member deposition was occurring near the fluvial/marine transition zone, the middle limestone Cedar Park and Keyes Valley Members were being deposited in the "clastic-free" waters of the southeast basin.

The Fredericksburg sea continued to transgress, in response to overall basin subsidence, resulting in migration of facies (Fig. 33). In the southeast portion of the basin, deposition of the Walnut upper unnamed marls was initiated. The upper marls reflect relatively deeper, normal marine conditions (Flatt, 1976, p. 35; Jones, 1966, p. 179).

Northwestward migration of facies persisted (Fig. 34), due to continual subsidence and decline in clastic influx.

Paluxy clastic deposition still existed in the northern marginal region with poorly developed limestones deposited in the adjacent basinward area (Figs. 12 and 13). The Cedar Park and Keyes Valley Members were deposited in the central portion of the basin in areas with only an occasional influx of terrigenous material, and are characterized by marked thinning to the north. Thinner accumulations may be attributed to a site of minor subsidence nearer to the basin margin. In the southern area, the upper marls were being laid down.

Contemporaneous with the deposition of the northern basin clays near the shoreline was the deposition of the Comanche Peak Formation in the southeast.

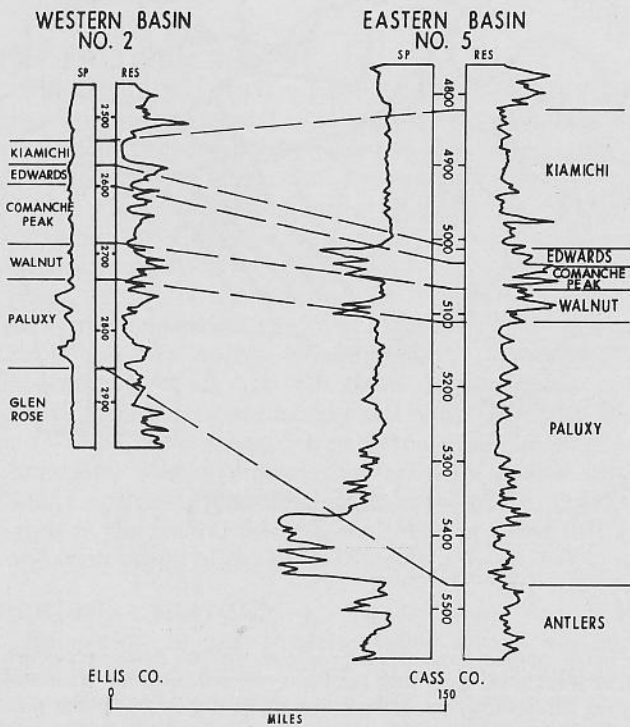


Fig. 24. Electric log signatures of the Comanche Peak Formation. The log response indicates predominant limestone lithology with thin interbedded shales. Both upper and lower contacts appear conformable. Note the slight northeastward thinning of limestone, a product of sedimentation and bathymetry.

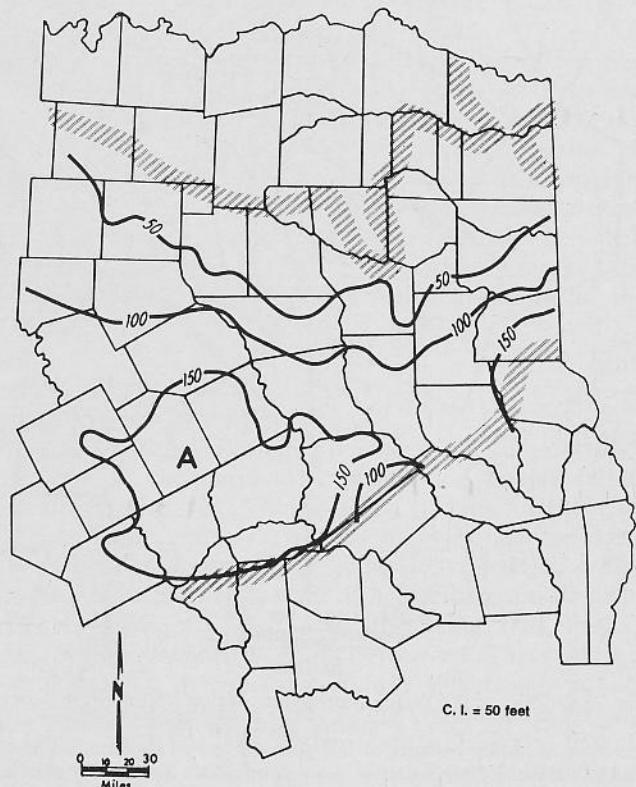


Fig. 25. Isopach of the Comanche Peak Formation. Gentle regional thickening is to the south. The hachured line is the line of gradation into the Goodland Formation. Beyond the hachured line, lower Goodland was deposited contemporaneously with Comanche Peak.

Eventually, deposition of the Comanche Peak sediments occurred throughout the southern part of the basin, with the lower Goodland (Comanche Peak equivalent) along the extreme southern margin (Fig. 35). The marine upper marls never reached the northern portion of the basin, where *Texigrypha* beds characterize the Walnut outcrop as far north as Grayson County (Sandlin, 1973, p. 55-56).

Late in Fredericksburg history expansion of the Fredericksburg sea resulted in more normal marine waters throughout the basin (Fig. 36).

Rudist migration is likely to have occurred along the shelf edge in shallower, more agitated waters. The gregarious nature of the rudists implies early formation of banks and mounds.

Clear, shallow marine waters covered the entire basin,

as indicated on outcrop by diverse fauna and lack of clastic material (Corwin, 1982, p. 49-50). Normal saline conditions prevailed; however, occasional shoaling restricted circulation, inducing conditions to become hypersaline. Evidence is seen in the vuggy dolomite and subtidal anhydrite occurrence in the basal Shell Johnson #1 core. In the northern basin, where the lower Goodland (Comanche Peak equivalent) was deposited, waters may have been somewhat muddy, as indicated by foraminiferal content, an abundance of mud-burrowing clams, and a high clay-limestone ratio (Beddoes, 1959, p. 68). Deposition of the Goodland in both the northern and southern marginal areas occurred simultaneously.

Edwards deposition marks the maximum extent of Fredericksburg seas. The presence of uniform Edwards thickness throughout the greater part of the basin, the similarity in thickness of both outcrop and subsurface, a consistent signature on electric logs, and the widespread extent of Edwards Limestone may indicate a single brief sea level rise, a pulse of subsidence, or a combination of both occurrences (Fig. 37).

With transgression, the shoreline retreated for great distances, as indicated by the absence of terrigenous sediments. Clear, normal marine to hypersaline waters existed as early as initial Edwards deposition, as evidenced by algae, foraminifera, and the echinoid

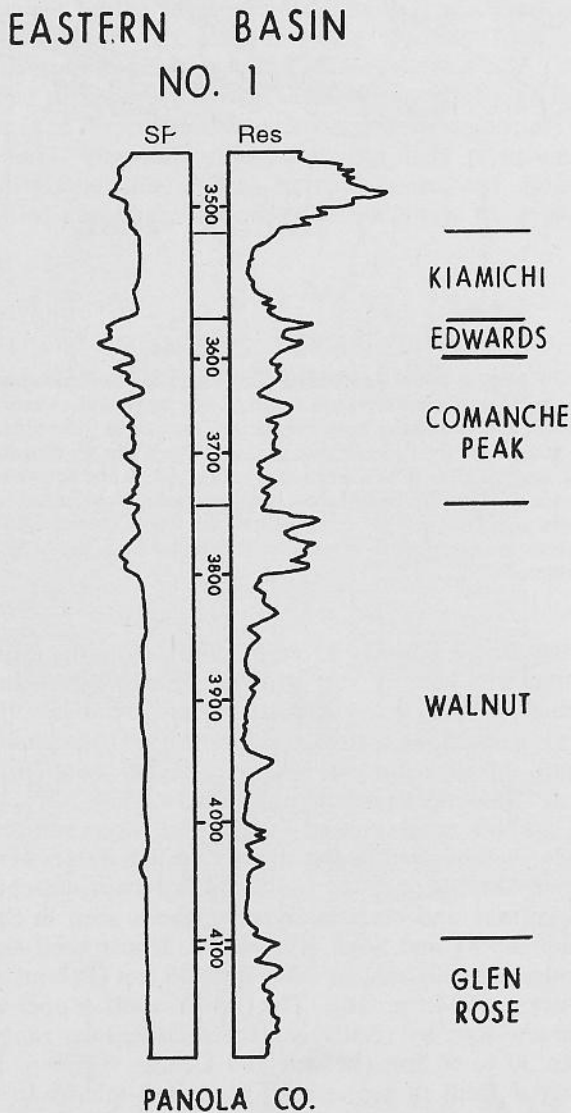


Fig. 26. Electric log signature of the Edwards Formation within the central portion of the East Texas basin. A strong resistivity "kick" most often characterizes the Edwards unit. The lower contact with the Comanche Peak is gradational and probably conformable. The upper abrupt contact with the Kiamichi suggests unconformity or a sudden change in depositional environment.

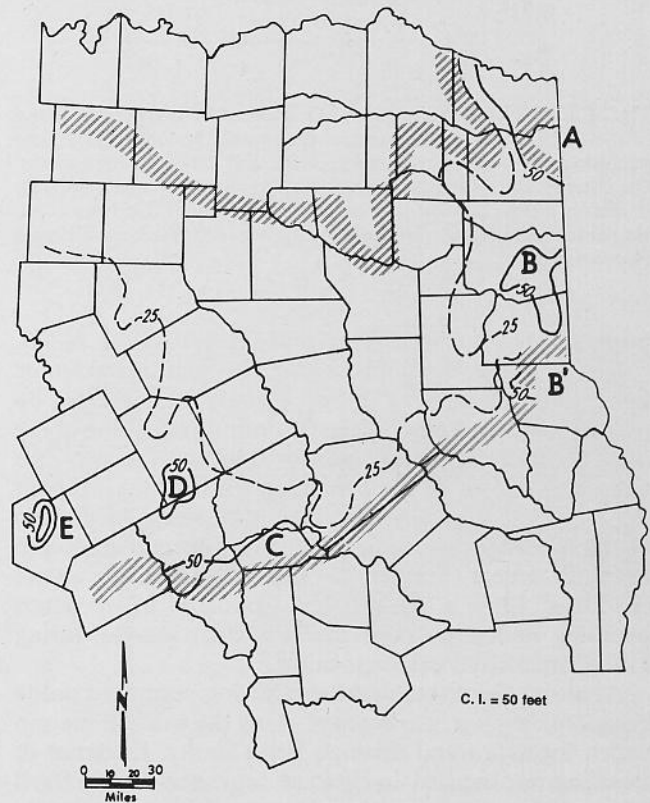


Fig. 27. Isopach of the Edwards Formation. The Edwards maintains a conspicuous thickness of 20 to 25 feet over the greater part of the basin. Marginal thickens are structure related. Hachured lines marking the southern and northern margins of Edwards isopachs represent the gradational zone with the upper Goodland Formation.

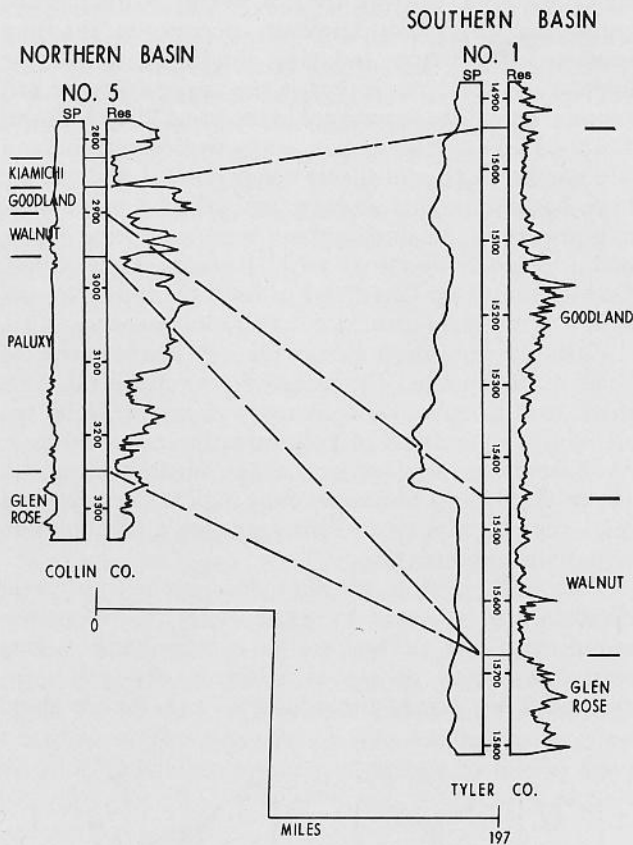


Fig. 28. Electric log signatures of the Goodland Formation. Goodland of the north is thinner than that of the south. The Goodland is time equivalent to both the Comanche Peak and Edwards Formations. On outcrop and in the subsurface, the Goodland reflects a decrease in clastics and an increase in carbonate content upward in the section, similar to the overall upward sequence in Comanche Peak and Edwards Formations.

population of the basal packstone (Corwin, 1982, p. 50).

Oolite shoals developed along the southeasternmost flank of the study area in Bell County (as indicated by oolitic grainstone and bioclastic-oolitic grainstone of the Shell Messer #1 core) and in Johnson County (the Cresson Member of the Goodland Formation) (Staples, 1977, p. 4). The Goodland of the north, deposited contemporaneously, indicates shallow normal marine to brackish waters (Staples, 1977, p. 55) and clear waters (Beddoes, 1959, p. 68-69). The Goodland of the south persisted under the same shallow, clear seas as during Late Comanche Peak deposition.

At about this time, slight shallowing permitted oolite shoals to develop into beaches along the western margin which forms a trend through Bell County. Evidence of shoaling is observed in upward sequence of the Shell Messer #1 core. Migration of tidal flat environments also occurred in the Bell County-Moffat Mound area. Evidence of such a regression is seen in the overall sequence of Shell Norwood #1 core.

Flourishing along the shelf edge were requienid rudist banks, as indicated by the requienid boundstone facies

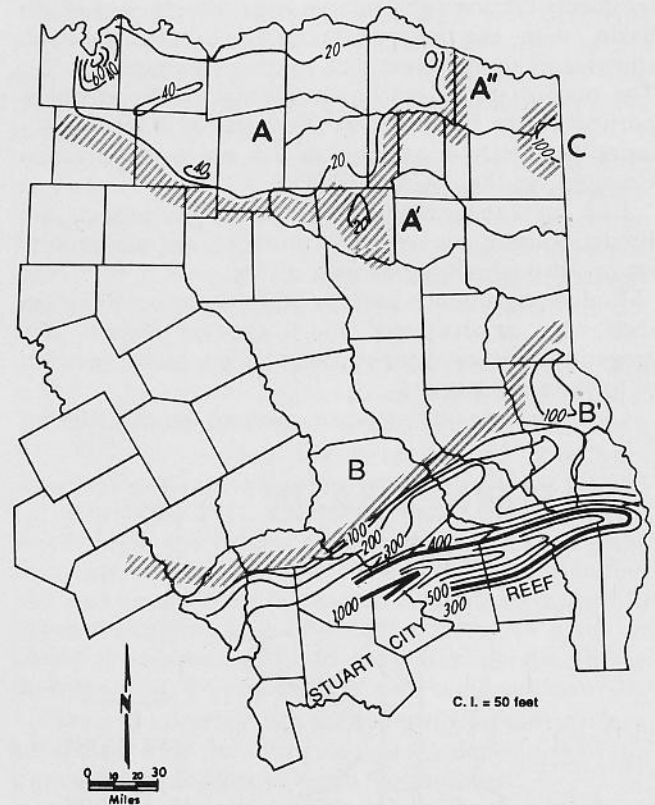


Fig. 29. Isopach of the Goodland Formation. The Goodland appears only in the extreme north and south of the study area, where the Edwards and Comanche Peak Formations can not be differentiated. The merging of the Edwards and Comanche Peak into the Goodland in the north is likely to be a function of sedimentation and bathymetry. Goodland deposition may reflect shallower conditions on a basin margin gentle slope. The remarkably thick Goodland section in the southern area is a result of continued sedimentation to match the subsidence rate.

in the Shell Chapman #1 core. Considering the critical criteria for healthy reef growth, clear warm waters, abundant light, good circulation, and relatively high energy conditions, water depths must have been shallow. Along the shelf margin, seas were highly agitated and 10 to 15 feet deep (Bebout and Loucks, 1974, p. 16).

Caprinid coral mounds and coral stromatoporoid patch reefs thrived in the slightly deeper waters of the upper shelf slope, as indicated by caprinid-coral-wackestone and coral-boundstone facies seen in Shell Chapman #1 and Shell Humble #1. Upper shelf slope depths probably ranged from 10 to 50 feet (Bebout and Loucks, 1974, p. 16). The lower shelf slope was characterized by relatively deeper conditions ranging from 30 to 60 feet (Bebout and Loucks, 1974, p. 14), inferred from the presence of abundant micrite in the intraclastic wackestone and stylonitic mudstone facies seen in the Shell Humble #1 and Shell Johnson #1.

The vast back-shelf lagoon encompassing the rest of the study area was probably submerged under depths of no more than 30 feet. Evidence rests in the uniform thickness of 25 feet throughout most of the basin and

the 30 feet of thickness maintained over much of the outcrop. The flat, uniform "table top" character of the rudist reefs in outcrop appears to be a reflection of maximum reef growth, which was limited by the water surface.

The end of Fredericksburg deposition was characterized by either a minor regression or a halt in sedimentation, resulting in an unconformity. Evidence for an unconformity includes the Kiamichi Clay-filled borings in Edwards surfaces, pitted upper surfaces, and effects of oxidation in the Edwards outcrop (Corwin, 1982, p. 38, 39); Kiamichi-filled borings in Goodland upper surfaces in North Texas and Oklahoma (Laali, 1973, p. 12-13); and brecciation and solution zones in a few subsurface Stuart City Reef cores (Bebout and Loucks, 1974, p. 12). However, no such occurrences were seen in the Stuart City Reef core in the present study.

Additional evidence of a possible unconformity is provided by the presence of dolomite crusts, burrows, discoloration (oxidation?), and leached zones in Norwood #1 and Messer #1 Edwards cores.

The presence of Kiamichi-filled burrows, discoloration, and brecciation is not necessarily indicative of subaerial exposure or erosion, but may represent a depositional hiatus. Such burrows have been cited in lithified carbonate sediments in sea floors from great

depths (Fischer and Garrison, 1969, p. 489; Bathurst, 1971, p. 363). Presence of such borings indicates a period of nondeposition in order for the process of intergranular cementation to occur (Bathurst, 1971, p. 363). Brecciation may be a result of subtidal slumping (Wilson and Jordan, 1983, p. 305). Thus it is possible that these occurrences represent a submarine discontinuity surface terminating late Edwards deposition.

However, so spotty is the information, that if indeed there was a regression at the end of Fredericksburg deposition, it may well have been on a local scale.

Structural Nature of the Basin

The regional structure of the basin was subdued. Absence of vertically stacked sedimentary cycles, lack of dramatically thick delta plain and prodelta facies, and absence of basinward thickening clastic wedges suggest that progradation exceeded basinal subsidence. Thus, slow uniform subsidence allowed rapid migration of facies across a broad flat surface. It is probable that migrating channels cut into subjacent delta facies during progradation, accounting for the presence of the point bar facies (seen in the McCrary #1 core) in the Lower Delta Plain environment (Fig. 5).

Sand distribution, thickness variations, and possible

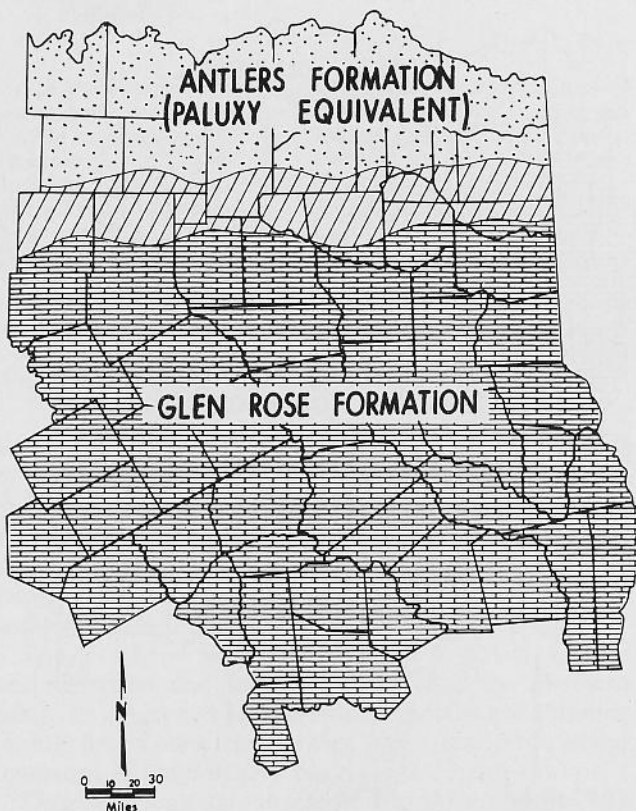


Fig. 30. Paleogeographic map A. Upper Antlers (Paluxy equivalent) clastics entered the northern basin in response to the retreat of the Glen Rose sea. This shows the initial Paluxy deposits to have a regressive component and to be time equivalent to the upper Glen Rose Limestone. White areas represent gradational zones between the formations. It is important to note that these lines are arbitrary.

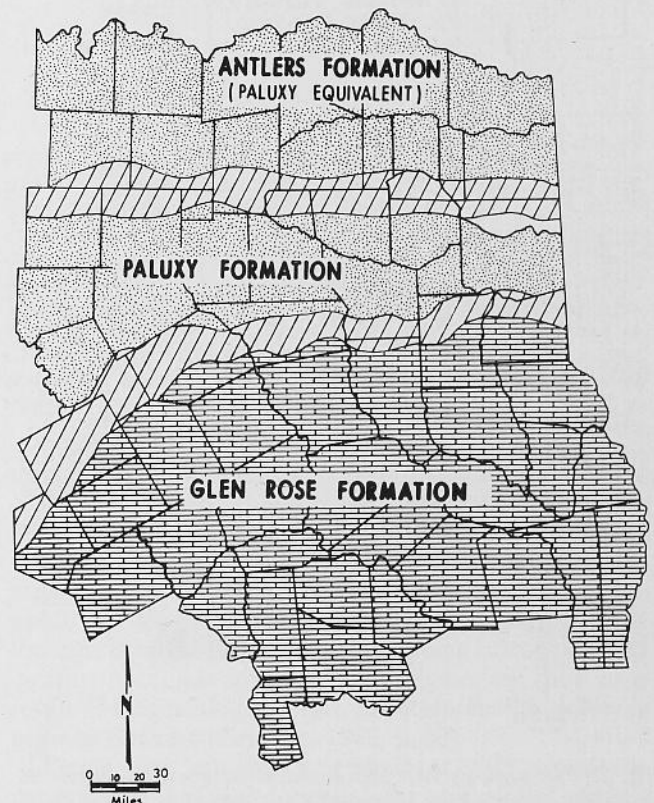


Fig. 31. Paleogeographic map B. Continued clastic influx created delta systems which rapidly prograded southward across a low energy, shallow water shelf. The northern basin was dominated by coarse land-derived clastics, while the southern basin was dominated by more marine shales and limestones during the maximum regression of the Glen Rose sea. White areas represent gradational zones between formations. It is important to note that these lines are arbitrary.

lateral facies changes can be linked to localized, salt-related structural activity (Seni, 1981b, p. 53). Fault adjustments on the northern perimeter of the Mexia-Talco system, possibly due to downdip Louann Salt creepage, allowed for greater Paluxy accumulation. Facies change across the fault system, from fluvial feeder tributaries to upper delta plain meandering channels, may have been triggered by simultaneous faulting.

Active growth of Van, Hainesville, and Hawkins salt anticlines occurred during Paluxy deposition. Paluxy distributaries apparently diverged upon reaching the positive salt features, accounting for the unusual thickness pattern (Seni, 1981b, p. 53). Thick clastic sequences are associated with anticline margins, while thin sand and shale units lie over the anticlines.

The remainder of the northern Salt Province was subject to rim syncline salt withdrawal related to adjacent diapir growth (Seni, 1981b, p. 54). Sedimentation matched lateral withdrawal movement, allowing great accumulation within rim syncline areas. However, limited well control used in this study limits the delineation of individual rim synclines.

The northern Antlers Formation thickness of 1300 feet in Grayson County is approximately equal to the cumulative thicknesses of its equivalents (Twin Mountains, Glen Rose, and Paluxy Formations) (Lemons, personal communication, Feb. 7, 1987). This suggests that the subsidence rate did not increase during early Paluxy time, but continued uniformly through the Trinity-Fredericksburg transition. Thus, the Paluxy clastic invasion and northward thickening wedge may be due to possible renewed uplift in the source area or the result of climatic change accompanying increased sediment input.

Contemporaneous with the slow subsidence in the northern basin, affecting Paluxy sedimentation, was subsidence in the southern basin influencing Walnut deposition. Differential downwarping may have been controlled primarily by thermal cooling (Bott, 1971, p. 319-327) (though actual evidence for this is absent) accompanied by localized salt-withdrawal and structural subsidence.

Initial Walnut sediments apparently draped over the Glen Rose reef paleotopographic high, as evidenced by the elongate thin south of and parallel to the Angelina-Caldwell Flexure.

Accelerated subsidence existed east of the Mexia-Talco fault zone in the southeast basin during basal

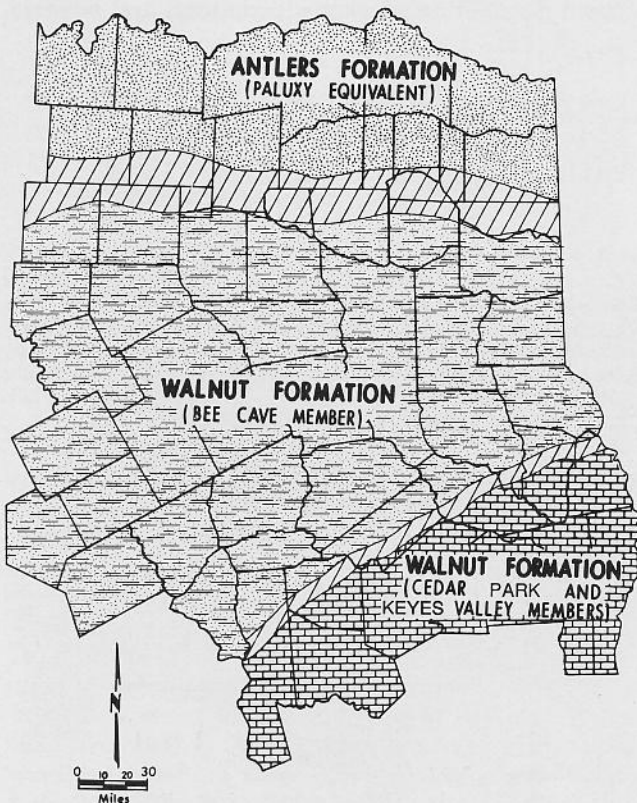


Fig. 32. Paleogeologic map C. Sediment influx gradually altered the deposition of Glen Rose Limestone to deposition of Walnut clays. Cessation of sediment input, accompanied by slow subsidence, allowed gentle inundation of the sea. This initial encroachment of the sea marked the beginning of the transgressive component in the Paluxy. In the clear waters of the southeast basin, middle limestones of the Walnut were being deposited. Overall basin subsidence remained slow and stable. Evidence of greater rates of local subsidence near salt features and fault zones are thicker Paluxy and Walnut accumulations. White areas represent gradational zones between formations. It is important to note that these lines are arbitrary.

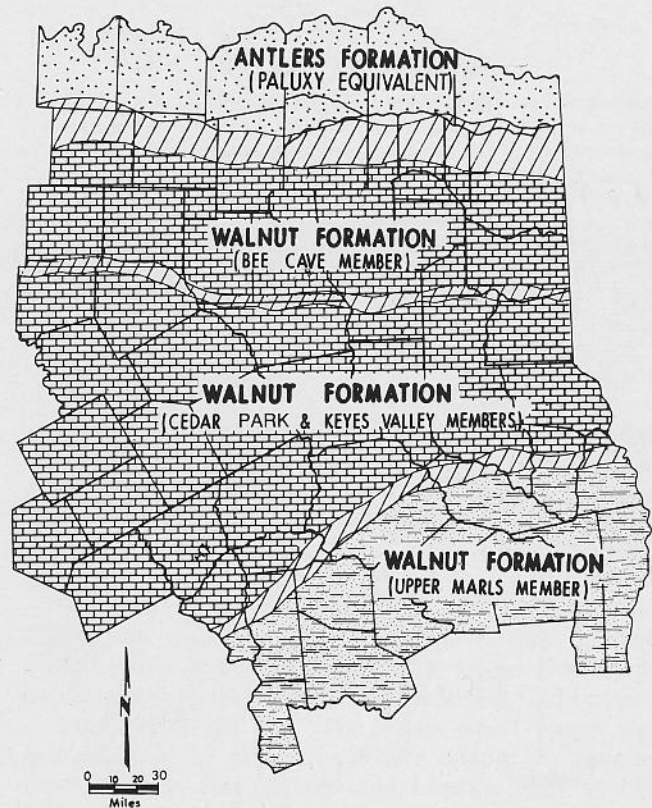


Fig. 33. Paleogeologic map D. The Walnut sea continued to transgress, depositing laterally adjacent Bee Cave clays, Cedar Park and Keyes Valley limestones, and upper unnamed marls. Paluxy (Antlers equivalent) sedimentation persisted in the extreme northern part of the basin. White areas represent gradational zones between formations. It is important to note that these lines are arbitrary.

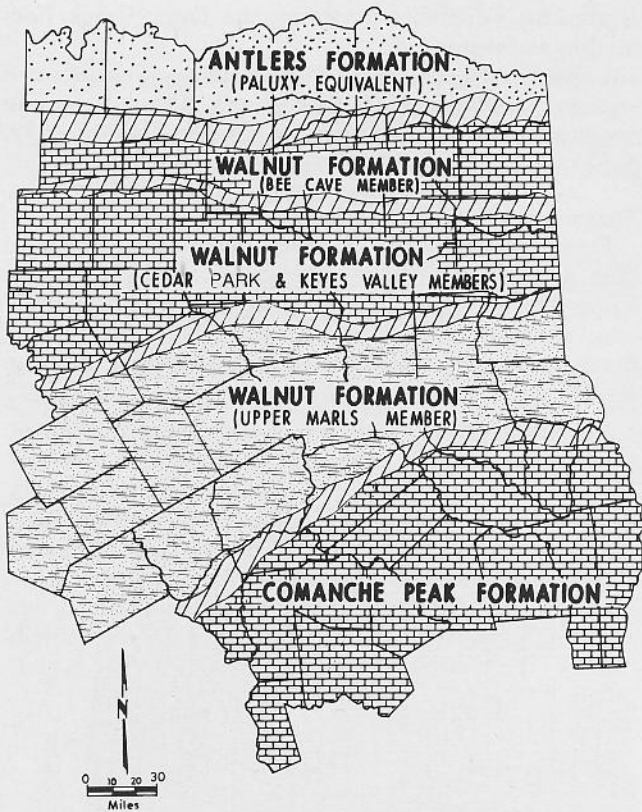


Fig. 34. Paleogeologic map E. Walnut facies shifted slightly northward as a result of continued subsidence and northward shoreline movement. Normal marine Comanche Peak sediments were deposited contemporaneously in the southeast portion of the basin. The Paluxy equivalent systems remained in the northern basin. Paluxy equivalent sedimentation persisted longer in the extreme northern basin due to the proximity to the source area and to the shifting of the shoreline. The Upper Antlers (Paluxy equivalent) in the northern basin records both the initial retreat of the Glen Rose sea and the northward advancement of the Walnut sea, and thus possesses regressive and transgressive components in its overall sequence. White zones represent areas of gradation between formations. It is important to note that these lines are arbitrary.

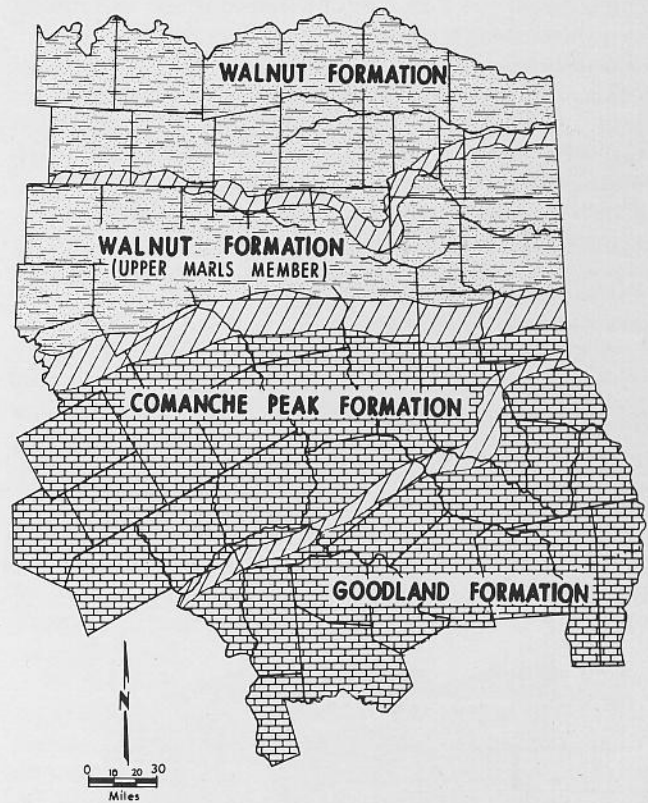


Fig. 35. Paleogeologic map F. Continued subsidence resulted in transgression of normal marine waters in the southern basin with Comanche Peak and Goodland (Comanche Peak equivalent) deposition. Predominant deposition in the northern basin was Walnut clays and marls. Occasional fresh water runoff probably prohibited the open marine upper unnamed marls to reach the northern region. The thin clay unit in the north reflects brackish conditions where *Texigryphaea* beds characterize the Walnut outcrop as far north as Grayson County (Sandlin, 1973, p. 55). White areas represent gradational zones between formations. It is important to note that these lines are arbitrary.

Walnut deposition (Fig. 25). The greatest accumulations of the lower marls are present in Anderson County, probably in response to salt-withdrawal related to early development of diapir growth. By late Walnut deposition, salt movement shifted and localized to northern Leon County, significantly increasing Upper Marl sedimentation (Fig. 12).

The northern basin was probably a site of less sedimentation and less subsidence than the southern basin, as evidenced by the marked northward thinning middle limestone units and thin upper marls and oyster limestone of the northern basin (Figs. 12 and 13).

Dominant regional subsidence during Comanche Peak deposition was evidently to the south-southwest (Fig. 25). Localized subsidence appears to have been on a low scale. Salt movement diminished significantly. Downwarping of the Cass Syncline increased somewhat, allowing thicker accumulation of Goodland sediment (Fig. 14).

The structural nature of the Sabine Uplift area is

uncertain. Granata (1963, p. 60) provided only general core descriptions as substantiation for a stable platform in the region (a porous, coquinoïd, chalky or crystalline limestone characterizing the uplift area and a dense, argillaceous, fossiliferous limestone representing the uplift flanks). It is possible that the thick, massive limestones of the region reflect increased subsidence and detritus accumulation. Differential porosity may be a result of diagenetic processes, as interpreted by workers prior to Granata (Granata, 1963, p. 60).

Accelerated subsidence, coincident with Goodland deposition, occurred south of the Angelina-Caldwell Flexure. Rudist bank sedimentation matched subsidence to maintain the necessary shallow water environment. The increased carbonate sedimentation further enhanced the subsidence rate.

Eventually, by Edwards deposition, the East Texas basin had stabilized to the same degree as the adjacent Central Texas Platform. There was then no basin, but a broader, more extensive carbonate shelf. The uniform

thickness of the Edwards in the subsurface and surface exposures strongly supports this conclusion.

Subsidence south of the Angelina-Caldwell Flexure continually matched sedimentation, as indicated by the lack of diastemic surfaces or minor unconformities throughout the Goodland (Stuart City Reef) core. Subsidence did exceed sedimentation at the close of Edwards deposition, allowing deeper water, dark-colored marine shales to be accumulated.

POST-FREDERICKSBURG

Depositional Environments

After a brief hiatus with lithification of the Edwards, water deepened and Kiamichi terrigenous material invaded the basin from the north. The configuration of the Edwards surface governed distribution, for the Kiamichi apparently thins slightly over reef accumulations and pinches out near the Belton High of Bell County (Shelburne, 1959, p. 114; Bishop, 1967, p. 179).

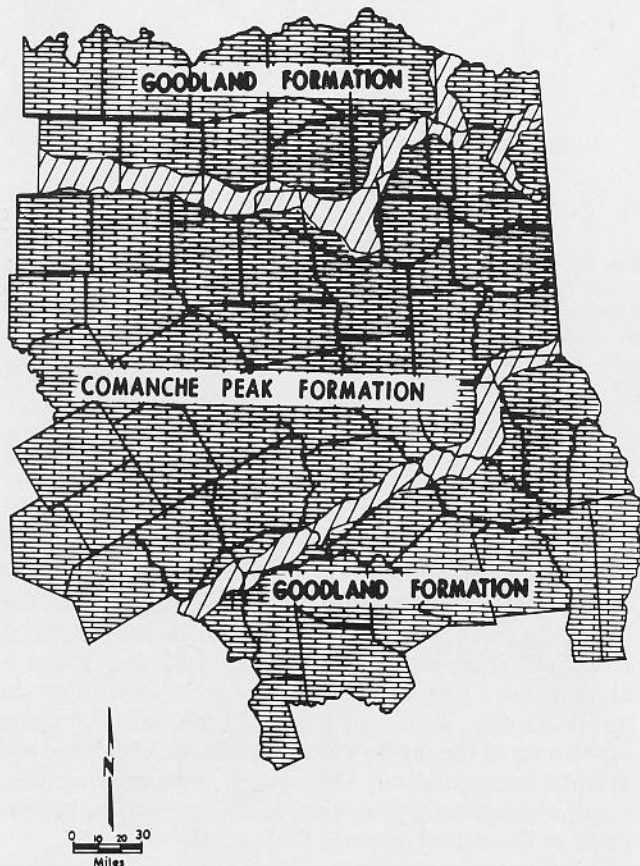


Fig. 36. Paleogeologic map G. Subsidence continued allowing an influx of normal marine conditions throughout the entire basin. Periodic runoff probably influenced deposition in the northern basin. Goodland (Comanche Peak equivalent) deposition occurred contemporaneously in the northern and southern portions of the basin. Subsidence in the north was minor in contrast to that of the south. South of the Angelina-Caldwell Flexure, sedimentation rate matched subsidence rate, allowing great thicknesses of Goodland to accumulate. White areas represent gradational zones between formations. It is important to note that these lines are arbitrary.

Beyond the Kiamichi pinchout, the Duck Creek Formation was deposited.

Expansion of the sea led to inundation of the western interior of the United States and allowed marine conditions to extend as far as Montana (Reeside, 1957, p. 513).

Structural Nature of the Basin

Downwarping of the basin was renewed by Kiamichi time, as suggested by the conspicuous thicks within the basin. The basinal axis was in the center of the study area. Salt movement may have contributed to some of the central basin thickening of the Kiamichi Clay (Fig. 38).

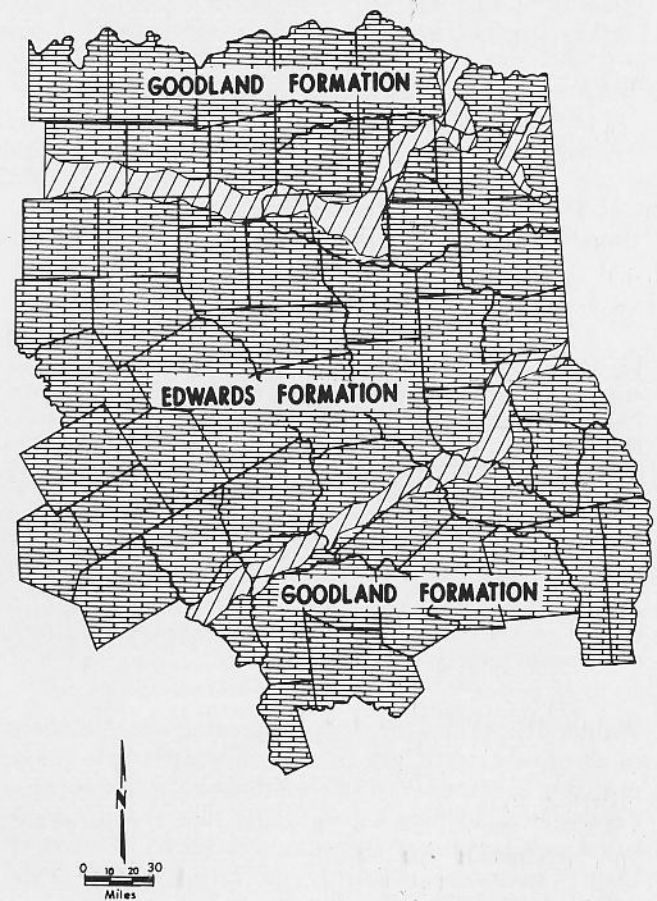


Fig. 37. Paleogeologic map H. Basinwide occurrence of a uniformly thick Edwards Formation suggests a possible brief pulse in sea level rise. Normal marine waters inundated the greater part of the basin. The Goodland (Edwards equivalent) was deposited contemporaneously in both the north and the south. The thin Goodland deposits of the north were apparently a function of sedimentation rate and bathymetry. The remarkably thick Goodland deposits of the south were a function of subsidence and sedimentation rate. The driving mechanism was probably subsidence, with the Angelina-Caldwell Flexure serving as the hinge line. Sedimentation load only augmented the subsidence. Both subsidence and sedimentation maintained equal rates, allowing for a substantial thickness of Goodland Limestone to accumulate. White areas represent gradational zones between formations. It is important to note that these lines are arbitrary.

SUMMARY AND CONCLUSIONS

1. The purpose of this investigation was to describe the stratigraphy of the Fredericksburg rocks of the East Texas basin, and on the basis of that description, to interpret their history and their relationship to the evolution of the East Texas basin.

2. The area of interest lies in northeastern Texas in the East Texas basin. It is bounded by the Ouachita fold belt, the Texas-Arkansas-Louisiana state borders, the Angelina-Caldwell Flexure, and the Central Texas Platform.

3. Principal methods used in this investigation included correlation and interpretation of electric well logs, construction of regional stratigraphic cross sections, construction of isopach and lithofacies maps, analysis of conventional cores, seismic interpretation, field reconnaissance in the Fredericksburg outcrop belt, and extensive literature research.

4. The Fredericksburg Group of the East Texas basin can be differentiated throughout the basin and can be divided into three stratigraphically distinct depositional

areas—northern basin, middle basin, and southern basin.

5. On the basis of the following evidence, the Goodland Formation is considered to be undifferentiated Edwards and Comanche Peak Formations and time-equivalent to both. The two distinct units show a striking similarity in overall upward trend (decrease in clastics and increase in carbonate content) and gradual thinning or thickening toward the undifferentiated section.

6. The Upper Antlers Formation of the northern basin is considered to be the equivalent of the Paluxy Formation. Distinguishing characteristics between Upper Antlers and Lower Antlers are electric log signatures revealing upper stacked sand bodies and lower thin, alternating sand and shale units.

7. The subsurface contacts between Fredericksburg formations appear conformable. The Edwards/ Kiamichi and Edwards/Duck Creek contacts are likely to be unconformable. The contact between the Goodland Formation and the Kiamichi Formation is probably unconformable.

8. Sand distribution, electric log character, spatial relationships, and core characteristics show four major Paluxy facies tracts and nine subfacies. Sixteen facies constituted the four Edwards environments. A network of seventeen Goodland facies make up the four shelf environments.

9. Fredericksburg deposition began with Paluxy River-dominated deltas prograding rapidly across a low energy marine shelf as the Glen Rose sea regressed. Clastic influx altered deposition from Glen Rose Limestone to Walnut Clay. Gradual cessation of terrigenous influx in concert with slow basin subsidence allowed encroachment of seas.

10. As the shoreline moved progressively northwestward, the basin received fewer clastics, and thus was influenced more by marine conditions, as recorded by the transgressive sequence.

11. By the time Edwards deposition occurred in the basin, normal saline to hypersaline marine waters prevailed. Conditions were uniform for the majority of the basin, possibly due to a sudden but brief rise in sea level.

12. Fredericksburg deposition was terminated by a period of either nondeposition or subaerial exposure, and the formation was later blanketed by the Kiamichi Shale.

13. Subsidence during Paluxy and Walnut deposition was greatest toward the central basin axis. Subsidence was enhanced locally by contemporaneous salt movement and fault activity.

14. During Comanche Peak deposition, subsidence shifted to the south-southeast, toward the actively subsiding shelf margin.

15. During Edwards deposition, a basin no longer existed. The area was a vast back-shelf lagoon landward from the Stuart City Reef trend. Although the East Texas basin was stable, forming the broad shelf lagoon,

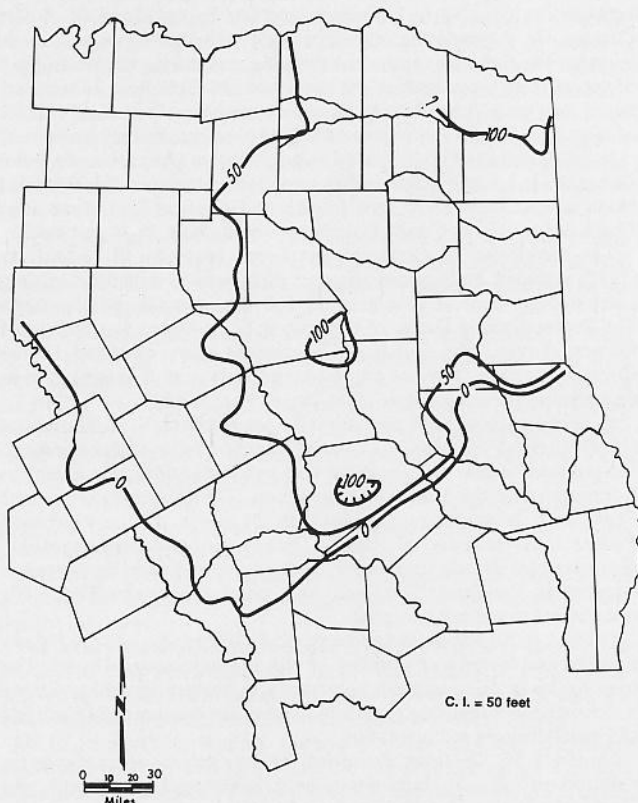


Fig. 38. Isopach of the Kiamichi Formation. Areas of greatest accumulation are in the central basin, apparently a result of increased subsidence. Basin subsidence was renewed at the beginning of Washita time. Beyond the zero contour in the southeast basin, Duck Creek Limestone overlies the Fredericksburg. Beyond the zero contact in the southern basin, the formation overlying the Fredericksburg is not known because of poor electric log quality.

relatively rapid subsidence occurred along the shelf edge.

16. Active basin subsidence followed Fredericksburg deposition as early as Kiamichi deposition. Post-Comanchean uplift on the Sabine Uplift stripped off

upper Fredericksburg units.

17. The Fredericksburg represents a relatively quiescent period of subsidence in the overall evolution of the East Texas basin.

APPENDIX:

PREVIOUS WORKS

The first significant contribution to the understanding of Cretaceous strata of Texas was made by a German geologist's observations in the south-central area of Texas. Ferdinand Roemer's geologic sketches, published in 1846 and 1848, concerned the division of Cretaceous rocks into the "Beds at the foot of the Highlands" (Austin Chalk-Gulfian) and the "Beds of the Highlands" (Fredericksburg-Comanchean). Unaware of the existence of the Balcones fault zone, Roemer misinterpreted the age of the beds forming the escarpment (Fredericksburg) as being younger than those at the foot of the hills (Austin). He did mention the possibility of a fault zone (cited by Thompson, 1935, p. 1508-1509).

G. G. Shumard served as a geologist for the United States Army in 1854. While in service, he mapped and named the Fort Washita limestone in the Red River area, north-east Texas (Thompson, p. 1509).

Jules Marcou was the first geologist to identify Lower Cretaceous (Neocomian) fossils in North America found in Texas and western Oklahoma. His findings were not readily accepted (Thompson, p. 1509-1510).

B. F. Shumard's work during his term as state geologist of Texas led him to publish a landmark paper in 1860 in the Transactions of the St. Louis Academy of Science. He first named, described, and arranged a stratigraphic sequence of Cretaceous rocks in Texas. He labeled his formations the Caprina Limestone, Comanche Peak Group, and Caprotina Limestone, which are presently recognized as Edwards, Comanche Peak, and Glen Rose Formations, respectively. Overlooking Roemer's mistake in age interpretation, Shumard also reversed the order of the Cretaceous sequence.

First to record the proper sequence of Cretaceous strata was R. T. Hill in 1887. His subdivision of the Cretaceous is still accepted today as the older "Comanchean Series" and "the Gulfian Series." Hill observed that the rocks west of Fort Worth shared similar fauna to those described by Roemer (1852) near the town of Fredericksburg. Using the formation names established by Shumard (1860), Hill named the rocks the Fredericksburg Division. Originally, he included Shumard's "Caprotina Limestone" as part of the Fredericksburg Division, but later, in an 1888 paper, considered it to be of late Trinity age.

In 1891, Hill recognized the Kiamichi Formation as part of the Washita Series and revised Fredericksburg Division nomenclature. At this time, he considered the "Caprina Limestone" as the uppermost formation of the Fredericksburg Division, renamed Shumard's Comanche Peak Group as the Comanche Peak Chalk, named the strata underlying the Comanche Peak Limestone near Bosque County the "Walnut Clays," and named and described the sand exposures near the town of Paluxy the "Paluxy Sand," including it within the Fredericksburg Division. Hill used the term Goodland in Oklahoma for the northern lateral correlatable units of the Comanche Peak Limestone.

The name "Edwards Limestone" was first used to describe the "Caprina Limestone" in 1898 by R. T. Hill and T. W. Vaughan. Included in the paper were interpretations that Paluxy was part of the Trinity Group and the Goodland Limestone was the northern equivalent of the Edwards and Comanche Peak Limestones.

A summary of Fredericksburg Group classification was presented by Hill in 1901. The Edwards, Comanche Peak, and Walnut Formations were discussed in detail, describing their lateral extent, thickness, and significance. The Paluxy Sand was considered part of the Trinity Group, although Hill commented that the Fredericksburg-Trinity boundary was difficult to determine.

L. W. Stephenson (1918) described the Goodland of northeast Texas and southern Oklahoma as a persistent three to six foot basal section of interbedded coquina-like limestone and thin dark marly shale and an overlying ten to fifteen foot section of hard, massive persistent limestone.

F. M. Bullard (1926) described the Goodland section in Marshall County, Oklahoma as 18-23 feet in thickness, consisting of a lower part of three feet of nodular marly limestone and an upper part of 15-20 feet of hard semi-crystalline, massively bedded limestone.

T. W. Stanton, in 1928, in a regional study on the extent of the Lower Cretaceous strata of Texas, correlated limestones in the Llano Estacado region with those of the Fredericksburg in the central area. He suggested that the sands beyond the northern Glen Rose Limestone pinchout should be assigned to the Fredericksburg Group rather than the Trinity Group.

Gayle Scott (1930) concentrated on the stratigraphic relationships between the Glen Rose Limestone and the Paluxy Sand in Parker County. He observed the interfingering of the limestones and sands and that the Paluxy's southward thinning was due to the lensing out of successively lower beds in the main body of Glen Rose Limestone. Scott interpreted the Paluxy Sands as the shoreward sandy facies of the upper Glen Rose, deposited during the Glen Rose regression.

F. M. Bullard (1931) described stratigraphy in Grayson and Cooke Counties, and noted a few inches of yellow calcareous Walnut Clay below a consistent 15-20 foot section of Goodland Limestone. The Goodland section in Cooke County averaged about 25-30 feet thick.

The description of Cretaceous rocks of Texas by W. S. Adkins (1932) included descriptions of areal distribution, structural setting, paleontology, general stratigraphy, and depositional environments. The Fredericksburg Group of the central Texas region was correlated to west Texas. The Goodland Formation was correlated to the Comanche Peak Formation, and the Edwards Formation was described as pinching out near the city of Fort Worth.

In compliance with the new rules of nomenclature, S. A. Thompson (1935) replaced "division" by "group" for the Fredericksburg section. He proposed a new classification with two formations, the Kiamichi Formation and the Gatesville Formation. The Edwards, Comanche Peak, and Walnut were reduced to members of the Gatesville Formation. Because of similar lithologic and paleontologic characteristics in the Comanche Peak and Goodland, he suggested eliminating the term Goodland and using Comanche Peak. His nomenclature was not accepted.

In 1937, in his last published work, R. T. Hill recognized the Paluxy Sand as the lowermost member of the Fredericksburg Group. The basis for his decision was new paleontologic and stratigraphic evidence which indicated that the formation marked the beginning of the cycle of Fredericksburg sedimentation.

In 1941, W. C. Ikins described Fredericksburg stratigraphy in easternmost outcrop localities, where he recognized Walnut and Comanche Peak as two distinct formations.

L. W. Stephenson et al. (1942) correlated the Lower Cretaceous outcrops throughout Texas, Oklahoma, Missouri, Illinois, and Kentucky, and into Mexico.

Following Hill's (1937) designation, F. E. Lozo, in 1949, considered the Paluxy Formation to be within the Fredericksburg Group. Four members were designated in the overlying Walnut Formation, a basal limestone member, a lower clay unit, a middle limestone member (Cedar Park), and an upper marl unit.

H. F. Nelson (1949) considered the relationship between the biohermal/biostromal facies and the interbiohermal facies of the

Edwards. He recognized (1) lateral gradation into one another with no structure, (2) lateral gradation with change of thickness as traced into bedding, thus structure exists, and (3) nongradation with interbiostromal facies onlapping or pinching out against bioherms.

J. P. Brand, in 1953, examined the paleontologic, stratigraphic, and structural relationship of the Cretaceous formations in the Llano Estacado region. He observed that the Trinity Group (Antlers Sand) and the Fredericksburg Group (Walnut Clay, Comanche Peak, Edwards) share similar lithologic and paleontologic characteristics with Callahan Divide equivalents.

W. H. Matthews, III (1956) studied the Fredericksburg Group as a whole, dividing it into 3 facies: (1) marginal or littoral facies; (2) neritic facies; and (3) biostromal facies. Emphasis was on description of the lithology and fauna of the biostromal facies of the Edwards Formation.

L. P. Beddoes (1959) identified an abundance of calcareous, benthonic forams in the lower Goodland section. In the upper part of the unit, an abundance of agglutinated benthonic forams was noted.

The Fredericksburg outcrop along the western margin of the East Texas basin was described by J. B. Jameson (1959). He divided the Edwards into four distinct facies. Subsurface analysis included log correlation and construction of isopach maps.

The Texas Bureau of Economic Geology, in 1959, published a series of studies on the Edwards Limestone with F. E. Lozo as the editor. Investigations by F. E. Lozo, H. F. Nelson, J. P. Young, and O. B. Shelburne established a framework for further work on this unit.

Fredericksburg Formations of north central Texas were correlated with adjacent subsurface units by F. E. Lozo (1959, p. 1-21). A cross section from Tarrant County to Williamson County showed thickness trends and regional unconformities.

H. F. Nelson (1959, p. 21-45) discussed the three modes of dolomite occurrence in the Edwards Formation. Dolomite occurs as primary, diagenetic, and post-lithification types. Nelson noted more extensive alteration occurs where the overlying Kiamichi Formation is absent.

The Kiamichi Formation in central Texas was divided into three facies by O. B. Shelburne (1959, p. 105-119). The Kiamichi was shown to be governed by the underlying Edwards facies. Shelburne attributed Kiamichi thinning to southward onlap of sediments on an uneven surface rather than an unconformity.

K. P. Young (1959, p. 97-104) established that a distinct fossil zonation exists within the Edwards Limestone in Bosque, Hill, and Johnson Counties. His paleoecological study concentrated on the use of fauna as depth indicators.

The Edwards Formation in Bosque County was studied in detail by W. R. Payne (1960). He concluded that biostromal facies were more prevalent than biohermal facies as a product of environmental conditions. The reef system flourished to the end of Fredericksburg time in the area. He noted also the Edwards-Comanche Peak contact varied from abrupt to gradational. He considered the Comanche Peak a time-equivalent lagoonal facies of the Edwards.

W. A. Atlee (1962) discussed the Paluxy Formation in terms of thickness, provenance, paleontology, and nature of the Paluxy-Walnut contact throughout the central Texas area.

J. G. Frost (1963) divided the Edwards Limestone of central Texas into three facies; inter-reef dolomite, massive reef, and back reef fine-grained dolomite.

The structural development of the Sabine Uplift area throughout Cretaceous time was investigated by W. H. Granata Jr. (1963), who believed the area was a broad relatively stable platform arch separating the subsiding northeast Texas and northwest Louisiana basins.

G. L. King (1963) studied variations of the Edwards Limestone of Coryell County, and associated carbonate build up of Edwards Limestone, the pinchout of Kiamichi Shale, and the pinchout of Paluxy Sand in Bosque County to the presence of a structural hinge that affected Fredericksburg deposition.

In the south-central region, outcrop lithologies and petrographic data were traced by C. H. Moore, Jr. (1964) to determine stratigraphic and facies relationships. He recognized six members in the Walnut Formation, with two being time-equivalent. An anomalous Edwards facies near Moffat, Bell County, he attributed to be the lateral equivalent of the underlying Comanche Peak to the northwest.

J. O. Jones (1966) described in detail the fossil and lithic content of the Walnut Clay, in which he recognized five members. Correlations from surface localities into the subsurface were made.

C. H. Moore and K. G. Martin (1966) studied the Paluxy Sand in Travis, Williamson, and Burnet Counties, describing the lithology, facies relationships, and depositional history. They divided the formation into five facies, and interpreted the sand as a product of a transitional environment between coastal and marine settings.

D. L. Amsbury (1967) examined Lower Cretaceous caliche horizons in central Texas and believed them to represent soil profiles. The existence of a soil profile in the Paluxy, Amsbury noted, provides a basis for subdivision of the formation into 2 members. He suggested division of the Antlers be handled in the same manner.

W. L. Fisher and P. U. Rodda (1967a) described the stratigraphy and mineral chemical properties of the Paluxy and Antlers of north-central and west-central Texas. Three facies were recognized in the Antlers, of which the upper facies was correlated to the Paluxy Sand.

That same year (1967b), the Edwards Formation was divided into three facies in a second publication by W. L. Fisher and P. U. Rodda. The facies included (1) a rudist-biohermal-biostromal facies; (2) a platform grainstone facies; and (3) a lagoonal facies. In addition, they named the area of restricted evaporite deposition the "Kirschberg lagoon." They also divided the dolomite of the Edwards into (1) stratal dolomite and (2) massive dolomite.

Comanchean stratigraphy and paleontology of Texas were highlighted in a Permian Basin Section of Economic Paleontologists and Mineralogists publication in 1967. Articles of importance to this investigation were written by O. T. Hayward, L. F. Brown, Leo Hendricks, and B. A. Bishop. Studies concentrated on lithologic and petrographic descriptions of the Trinity, Fredericksburg, and Washita Groups.

Recognition of a regional caliche facies in the basal Cretaceous in areas of the Callahan Divide and Lampasas Cut Plain by Castle (1969) allowed for correlation between Paluxy and Antlers equivalents. This caliche horizon serves as a marker between the Paluxy and Trinity Sands within the Antlers Sands. He interpreted the caliche as being progressively younger eastward as it developed on Paluxy deltaic sediments.

Edwards dolomite facies of central Texas delineated by W. L. Fisher and P. U. Rodda (1969), form a concentric belt bordering the lagoonal facies of the Kirschberg lagoon. The origin of the two types of dolomite differed in timing element and physical environment. Stratal dolomite, most common of the southern lagoonal margin, preceded lithification primarily as a result of supratidal conditions. Massive secondary dolomite was explained by a seepage-refluxion model.

Stuart City reefs and El Abra reefs were compared to modern analogs by L. S. Griffith, M. G. Pitcher, and G. W. Rice (1969). These systems have certain elements in common with Florida Bay reefs. All have linear barrier systems separating shallow water carbonate platforms from oceanic deeps.

Moore's (1969) stratigraphic and regional facies framework of west central Texas incorporated the Fredericksburg rocks of the Lampasas Cut Plain, the Callahan Divide, and the northern Edwards Plateau region. Moore introduced the term "Walnut-Comanche Peak undifferentiated" for the carbonate sequence in the Callahan Divide. The pre-Washita unnamed upper formation containing the "Dr. Burt Ammonite Bed" was extended by Moore from the Edwards Plateau to the Callahan Divide.

The Skelly-Hobbs Rudist Reef Complex (Marcantel, E. L., 1969) defined the geometry, four facies, and the depositional history of this complex. He recognized the areas as a Fredericksburg topographic high, a broad, shallow-to-emergent platform allowing supratidal conditions. Nine facies were described. Depositional history was reconstructed by use of regional lithofacies maps and he described the dolomite sequence of west-central Texas as correlative with the Kirschberg evaporite of the Edwards Plateau.

The Fredericksburg section of the Callahan Divide was divided into seven time-equivalent depositional units by A. L. Boutte (1969), who based the division on bored surfaces. Depositional conditions were similar to those for the Walnut, Comanche Peak, and Edwards Formations.

Perkins (1969) noted that five of the seven rudist families are present in the Edwards Formation. The paleoecology of these sessile, marine bivalves varies with each family.

M. A. Mosteller (1970) discovered evidence of tectonic and/or salt withdrawal movement within the Mexia-Talco fault zone through subsurface correlations made in the southeast East Texas basin. Salt

withdrawal was concentrated in Anderson County, and the Texas Craton and Stuart City Reef trend were structurally stable during Comanchean time.

The Antlers Sand in the Callahan Divide was described by C. C. Smith in 1971, who agreed with Castle (1969) that the caliche layer represented an ancient soil horizon. Smith proposed that the Fredericksburg/Trinity boundary be placed at the caliche zone.

P. A. Boone (1972) also considered the Antlers Formation in a broad region of west-central Texas. Eight facies were recognized: point bar, floodbasin, delta, marine bar, bay-lagoon, terrigenous, shallow shelf, and open marine platform carbonates.

The Golden Lane and Poza Rica Reef trend of eastern Mexico were studied by A. H. Coogan, D. G. Bebout, and Carlos Maggio (1972), who concluded that these trends are time equivalent to the Stuart City Reef trend. The depositional facies of the two trends were found to be similar, but the geologic histories were believed to have been different.

The Comanche Peak-Edwards contact was studied by W. A. Mudd (1972) in McLennan, Coryell, Hamilton, and Bosque Counties. Initial Edwards deposition began with *Eoradiolites* attachment to three different substrate types (1) *Dictyoconus* mats; (2) *Cladophyllia* mats; and (3) burrow-solidified carbonate mud.

A study of circular bioherms and elongate biostromes of central Texas by D. S. Roberson (1972) concluded that elongate wave-resistant reefs along the platform margin protected the back reef mounds or bioherms. Elongate reefs grew laterally, while cone-shaped bioherms grew radially and upward to a specific height.

The Edwards Group of south central Texas was investigated by P. R. Rose (1972), who utilized field and subsurface data to establish depositional history. Rose proposed as new formation names in the Edwards Plateau, the Fort Terrett and Segovia. Along the Balcones fault zone and San Marcos Platform he divided the Edwards Group into the Person and Kainer Formations. He defined nine depositional environments on the Comanche Shelf: open deep marine, open shelf, open-shallow marine (moderate to high wave energy), open-shallow marine (low wave energy), restricted shallow marine, tidal flat, euxinic-evaporitic shelf basin, evaporitic-dominated supratidal flat, and coastal terrigenous.

Hooman Laali (1973) described borings in top of the Goodland Formation filled with Kiamichi Clay in Tarrant County, Texas and Choctaw County, Oklahoma. He interpreted this as evidence of an unconformity.

S. A. Mizell (1973) defined three petrographic facies of the Edwards in McLennan, Bosque, and Coryell Counties, lime wacke-boundstones facies, calcarenite facies, and coarse calcarenite facies, and interpreted them as products of wave action related to proximity to the reef core.

Within Bosque, McLennan, and Bell Counties, Edwards relationships to adjacent formations were established by H. F. Nelson (1973), who noted that secondary dolomite present at most localities differed from that of the Kirschberg lagoon facies to the west.

A study of the Goodland of north central Texas, completed by Sandlin in 1973, included stratigraphy, physical character, paleontology, structure, petrography, chemical character, and depositional history. He concluded that the Goodland and the Comanche Peak share the same lithologic characteristics, thus are adjacent parts of the same lithosome.

D. G. Bebout and R. G. Loucks (1974) described five environments of Stuart City Reef deposition in south Texas: (1) shelf lagoon; (2) shelf margin; (3) upper shelf slope; (4) lower shelf slope; and (5) open marine. Diagenesis had destroyed original porosity.

Extent of oyster banks, fossil assemblages, and lithology of five members of the Walnut Clay of central Texas were described by C. D. Flatt (1976), who concluded that lithic variations reflect slight variations in environmental conditions.

Steven L. Keyes (1976) focused on the relationship between the Edwards' upper surface and overlying Kiamichi sediments. In agreement with earlier work, Keyes considered the Kiamichi Member part of the Georgetown Formation unconformable with the Edwards Formation. Thus, the Edwards marks the termination of a transgressive cycle.

G. B. Lambert (1976) discussed the diagenesis of the Edwards Formation of central Texas, and concluded that diagenesis began with marine cementation and pyrite formation. Dolomitization was the product of contemporaneous seepage refluxion and silicification.

Dissolution followed. Subaerial exposure introduced phreatic cementation. Present diagenetic changes are in the form of karst solution and travertine deposition.

T. A. Bay, Jr. (1977) constructed regional cross sections of Fredericksburg and Washita groups across the Central Texas Platform to determine the sequence and depositional history. Using seismic profile, he also identified the Glen Rose as the product of deposition on a ramp and Fredericksburg-Washita rocks as indicators of deposition on the shelf margin.

C. A. Caughey (1977) recognized three major facies in the subsurface Paluxy Sand in the East Texas basin: (a) a delta facies; (2) a fluvial facies; and (3) a strandplain facies.

Five of the six families of rudists are present in Fredericksburg rocks according to works by A. H. Coogan (1977) who described the morphology of each family.

A. D. Jacka and J. P. Brand (1977) studied two diagenetic zones within the Edwards Formation, to provide a diagenetic history including marine diagenesis, early diagenesis (micritization and vadose-phreatic groundwater diagenesis), and late diagenesis (calichification and silicification).

Kerr (1977) reviewed the history of the Moffat Mound of Bell County and recognized six major lithofacies, reflecting progradation. Three stages of diagenesis were defined in his work.

Sue L. Keyes (1977) divided the Comanche Peak Formation of central Texas into 3 facies: (1) a lower unit of thin *Texigryphaea* beds and nodular limestone; (2) a middle unit of nodular limestone, thin-bedded limestone, and marl; and (3) an upper unit of chalky bioturbated limestone and marl. She believed the facies represented variable salinity conditions.

E. McFarlan, Jr. compared the transgressive-regressive cycles of the Lower Cretaceous sediments in the Gulf Coast with a global cycle of eustatic sea level fluctuations and concluded that major transgressions and unconformities correlate, but the minor events of Fredericksburg time do not correspond.

Michael Molina (1977) studied the coral-rudist relationships in the Edwards Limestone. He interpreted the assemblage as a life-death association, with the dead corals serving as a woven framework to which the living rudists were attached.

The Stockton Plateau-Big Bend area was studied by R. W. Scott and E. J. Kidson (1977). Their work established four depositional environments for the Lower Cretaceous in that region—a coastal plain, carbonate shelf, platform/shelf margin, and shelf basin.

The Goodland was divided into three members based on lithology and paleontology by M. E. Staples (1977). He concluded these members were time-transgressive deposited in brackish water lagoon and clear open-marine environments. He considered the Goodland the northern equivalent of the Comanche Peak.

G. B. Lambert (1979) recognized five facies and two micro-facies within the boundstone reef facies of the Edwards Formation. He interpreted vertical and lateral facies relationships to indicate an offlap of near-shore restricted marine limestone over more offshore open marine sediments.

M. T. Owen in (1979) described the Paluxy Sand at the outcrop belt and defined three members reflecting initial deposits of tidal flats and beach, overlain by deposits of braided streams, again overlain by deposits of meandering streams, intertidal zones, and marine subtidal zones.

M. B. Weems (1979) believed the Edwards lacked "true reef" characteristics of in-place accumulation and wave resistance, suggesting the alternate term of "rudist bank" be used to describe the Edwards. Four facies were described in her investigation: rudist biohermal-biostromal, flank bed, interbank, and dolomitic.

Through seismic stratigraphy, evidence of salt movement during Upper Jurassic along the northwest margin of the East Texas basin was detected by M. P. A. Jackson and D. W. Harris (1981). Similar trends along the northwest margin exist in younger Cretaceous units in the central portion of the basin, as shown by the present study.

S. J. Seni (1981a) discussed several depositional fluvial facies in the Paluxy (strandline, destructional delta, barrier bar, embayment, and fluvial). He recognized a northern provenance in the Arbuckle-Ouachita System. Salt activity had minimal effect on facies distribution because sand input decreased toward basin center, where salt flowage was most active.

S. J. Seni and C. W. Kreidler (1981) suggest three phases of infill

of the East Texas basin. The initial stage involved uplift, rifting, rapid fault controlled subsidence accounting for the thick rift fill, evaporites, and sand thickening toward the basin center during Triassic, Jurassic, and Lower Cretaceous. During the middle phase, which includes deposition between the Massive Anhydrite of the Lower Glen Rose and the Upper Cretaceous Navarro Group, the basin was more stable. Again declined rates of sedimentation and subsidence occurred in the final phase, with Tertiary fluvial and delta systems filling the formerly marine basin.

S. J. Seni (1981b) studied depositional systems and salt-related activity during Paluxy time. Thickness variations which occur along the northern periphery (Mexia-Talco fault zone), and basin center are associated with paleotopographic synclines.

Salt structure patterns within the East Texas basin were recognized by O. H. Wood (1981). Salt domes occur primarily along the axis where overburden was the greatest and Louann Salt the thickest. Salt diapirs exist along the periphery. Anticlines are scattered, but most abundant within the basin center.

Linda Whigham Corwin (1982) discussed in detail the Fredericksburg stratigraphy north of the Colorado River. The nature of overlying and underlying contacts, as well as those contacts between formations were included. Subsurface log correlations were made along the western margin of the East Texas basin. Depositional history of the Fredericksburg incorporated the outcrop exposures and subsurface data.

The East Texas basin margins are outlined by structural features

dating from Pennsylvanian to Tertiary as noted by M. P. A. Jackson (1982). The three major fault systems of the basin, the Mexia-Talco, Elkhart-Mount Enterprise, and Central Basin, he believed occurred in response to local and regional Louann Salt movement.

The anomalous Edwards thickening in Bell County, the Moffat Lentil, was given special attention in 1984 by D. L. Amsbury, T. A. Bay, Jr., and F. E. Lozo. Core analysis showed the Lentil to be a persistent shoal bounded by lime wackestone and marl to the northeast and tidal flat sediments to the southwest.

The Upper Antlers Sand in north Texas was correlated to the Paluxy Formation of central Texas by J. C. Brothers (1984). The deposits reflect a brief period of deposition braided streams, followed by a depositional hiatus and caliche development. Deposits of meandering systems overlie the caliche section. These are in turn buried by Walnut Clay. Three major input avenues were defined by Brothers and described as reactivated paleodrainage systems.

B. R. Man (1984) interpreted the depositional history of the East Texas basin in Fredericksburg through trends of electric log signatures and lithologic descriptions of the Fredericksburg section. Type log and signature descriptions were given for each horizon.

The Upper Fredericksburg was studied by A. D. Walker (1984), who focused on the transition of the Goodland into other Fredericksburg units. Two north-south cross sections were constructed, one surface and the other subsurface. She concluded that the Goodland shared facies with the Comanche Peak, but is time-equivalent to both Comanche Peak and Edwards Limestone.

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